Proceedings

1978 CALIFORNIA PLANT and SOIL CONFERENCE

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CALIFORNIA CHAPTER–A.S.A.

Sheraton Inn
Fresno, California
January 25, 26 and 27, 1978

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AMERICAN SOCIETY OF AGRONOMY

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CONFERENCE REPORTS

AIR POLLUTION AND AGRICULTURE

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Air is omnipresent, at least in the envelope surrounding the earth to elevations of the few thousand feet where most people live, raise their crops, and develop industry. It is so vital that its presence is taken for granted. Its principal components, oxygen, nitrogen, and carbon dioxide, have been and are present in the right proportions to allow life to develop as we now know it. Because of these elementary facts, air is not generally thought of in resource management for agriculture in the same sense as are land, water and energy. The agriculturalist does have some control over the latter three resources and does manipulate them, often rather drastically, as a fundamental part of his operation.

The farmer does not plan his day's work by deciding whether to order some air for his crops as he might decide to irrigate, use certain types of energy, or even develop a new piece of land. He takes for granted that the air is there. Air was not being used up. The supply was constant and did not vary year to year as might the supply of water, energy, or land. The major change that has occurred during the past fifty years is that our air has become contaminated with minute quantities of toxic gases because of man's total activity. The air quality has deteriorated and most of it is of our own doing, because of the things we want: transportation, food, all forms of energy, clothes, building materials; that is, any item that requires energy for its production. The by-product of the energy required for transportation and manufacturing is air pollution.

We find that the air is polluted mostly where man has congregated into relatively large communities. As an example, if we were to visualize a map of California and draw a line east and west through Marysville and south along the Sierras, we find that more than 90 percent of the people, industry and agriculture occur south and west of that line. Also, this is where most of the agriculture effects of air pollution in the state occur.

We have developed a great deal of basic information over the last several years. The gases that are toxic to vegetation are fairly well known. The oldest and best known of these are sulfur dioxide and hydrogen flouride which come principally from many kinds of manufacturing processes. These sources are stationary and the damage to vegetation is usually restricted to the local area. Peroxyacetyl nitrate (PAN), ozone, ethylene, and nitrogen dioxide are relatively new components of air pollution and arise as photochemical reaction products of exhaust gases from the automobile. Since this source is mobile, the plant damaging effects are wide spread and may be found throughout an entire air basin such as the south coastal area of California. Even newer components, in which interest is developing, are hydrogen chloride from the burning of plastics, and hydrogen sulfide from geothermal sources.

Many of the effects of pollution on crops are also well known. The acute injury occuring on affected plant leaves is generally distinctive for each pollutant and is used to identify the responsible toxic gas. Leaves are the site of the injury that we see because this is where normal gas exchange takes place in growing plants and the toxic gases, once they enter the leaves, have the capability of killing cells or altering their basic function so that varying portions of a given leaf appear to be injured.

The relative losses sustained from such injury depends on the type of crop being grown. Injury is particularly serious economically when the leaf or flower is the marketable portion of the plant, such as in lettuce, spinach, alfalfa, or roses and orchids. The effect may be less serious but still highly significant on crops where the marketable portion is other than the leaves, such as in citrus, grapes, tomatoes, potatoes, and cotton. Leaf injury on the former crops could cause 100 percent loss to the grower. The same amount of injury on the latter plants might reduce yield and quality of the product but the grower could still harvest his crop.

Pollutant concentrations that are lower than those that cause acute or visible injury may suppress the growth of affected plants thereby significantly reducing yield and impairing quality as measured by altered nutrient value and vitamin content. These latter effects can be determined only with very careful comparative studies, that is, growing plants in clean air versus polluted air. In the end, these growth suppression effects may be more important than we have been led to think.

Some information still needs to be developed. We need to have better estimates of losses. To quote from the Department of Food and Agriculture, "we need to provide reliable data for making more meaningful crop loss estimates". Because we are dealing with dynamic biological systems the current ability to predict effects of air pollution episodes is relatively poor since so many variables determine whether a plant will be injured and the degree to which loss will be sustained. As an example, temperature, light, humidity, water stress and age of a plant all govern how severely a plant of given susceptibility will be injured. If these factors are at steady state, additional variables are species, genetic variety and duration of exposure. Threshold concentrations, that is, those lower concentrations causing growth suppression without visible injury, need to be studied in more detail. This leads to the important question of the trade-off between being willing to accept the cost of some crop losses as opposed to the cost of trying to remove the last bit of pollution. More needs to be done on synergistic action between pollutants. This becomes especially important as air pollution control methods bring us nearer the threshold concentrations just mentioned. Experiments have already demonstrated that low concentrations of ozone and sulfur dioxide which have no effect when occurring alone, may have serious effects if they occur together.

It has been stated above that economic loss to agriculture from air pollution stems principally from reduced yield and impaired quality of the product. On direct losses alone the Department of Food and Agriculture estimates an increase from about $16 million in 1970 to $51 million in 1974. The change is not necessarily due to an increase in intensity of air pollution, but is more directly related to the increased dollar value for the crops affected.

The problem for the agriculturalist is aggravated because of the continuing expansion of urban sprawl into rural areas. The line of demarcation is becoming less distinct. The unique vegetable growing industry of Los Angeles County has all but disappeared because of combined urban growth and accompanying air pollution. The same fate may be in store for the rich Salinas Valley. It is interesting to note that the Department of Food and Agriculture does not presently report any losses from this Valley, but as more people move into the area, which in turn requires more services, damaging pollution may become a fact of life. The San Joaquin Valley is not exempt. Losses to cotton alone in this Valley were reported at over $26 million in 1974, almost half of the dollar loss reported for the state. We noted pollution effects in the San Joaquin Valley as early as about 1955, and this in the absence of any large industries; just more people and their automobiles.

As far as direct management is concerned, there is little the grower can do to manage the air for his crops. He cannot order in a new supply of air for a given period of time as he does water. The air can be cleansed for small, enclosed operations such as those growers who use greenhouses. This is done by installing activated carbon filters on the outside of the house and constantly passing air through the filters and into the house at a rate sufficiently high to keep the house under positive pressure. If a grower must stay in an area, the selection of varieties that have shown resistance in the field can be used as a management tool. Variation and sensitivity within varieties of several crops has been noted. Also genetic resistance has been noted at least in onion, corn, spinach, potatoes, and tomatoes. Large scale breeding programs with a specific aim of developing crops resistant to air pollution generally have been undertaken in order to solve air pollution problem.

The grower can move away from local stationary sources of air pollution. He could move perhaps a few miles or over into the next county, and get away from a local source of sulfur dioxide, flourides, or some other material. Or, he might have to move a long distance to get away from a large air basin that is filled with the smog due to the automobile. But before moving, he needs to know that the new area will be pollution-free for a considerable period of time and that it provides the desired market, transportation, water, and perhaps other needed services. As an example of moving a long distance, I can cite an experience in Denver about 1954. This had been my home and I noted that the petunias in my parents garden had the typical Los Angeles type damage on the under surface of the leaves. I took the time to do a general survey of the Denver area and found that plants in the Civic Center were very heavily damaged so I went to the relatively rich vegetable growing area north of town. As I walked through a field of spinach, the grower came out and asked what I was doing. I indicated that he probably wouldn't know what I was talking about; but I was looking for smog damage. He, with expletives that have to be deleted, said that he did because he had been a vegetable grower in the Los Angeles area and had moved to Denver to get away from smog. Now, I was telling him his crops might be damaged here. Fortunately, at that time there was no damage. Denver has since developed a very serious air pollution problem and I'm quite sure that if this area were to be surveyed, it would not be difficult to find smog injury. So here was an example of a farmer who moved a great distance to get away from air pollution and perhaps had only a relatively few years for growing healthy plants.

The real solution, of course, is to control pollution at the source. It is slow, tedious, and expensive. For us here in California, we should take some comfort in the fact that our state leads the nation in these efforts.

On the other side of the coin is the fact that agriculture is a source of air pollution through the burning of agricultural crop wastes. Some of the same gases are produced from these fires that come from the automobile and some manufacturing sources but the relative quantities are much less. The more important effect right now seems to be the visible smoke from such burning. Some of the effect is an esthetic deterioration of the air, but the effect may be much more serious where airports are situated in areas where burning is done or principal highways transverse the area. So far as we know, the smoke itself does not have any direct effect on plants, although there has been the suggestion that the clouding of skies cuts down the sunlight and therefore effects the growth of plants. But this would be a relatively temporary situation. Nevertheless, maintaining the quality of the air for our state has imposed a management problem on the grower. He can either stop burning and find alternate methods of disposal or he can adhere to the burning restrictions.

Growers themselves have made considerable strides in reducing the amount of burning and much of this was accomplished before there were stringent rules regulating burning. In the south San Joaquin Valley only about 12% of the total agricultural waste generated is burned, and this certainly speaks well for the farmers. The restrictions that we talk about for determining whether crops residues will be burned are based upon meteorological considerations. The rice growers in the Sacramento Valley pioneered this effort on a volunteer basis before the law came into effect. As an example of the implementation of this meteorological system, a burn day is announced for the San Joaquin air basin when all the following criteria are satisfied:

1) Near the time of day when the temperature is at a minimum, the 3,000 ft. temperature is not warmer than the surface temperature by more than 13° F.

2) The expected 3,000 ft. temperature is colder than the expected surface temperature by at least 11° F for four hours.

3) The expected day time wind speed at 3,000 ft. is at least 5 miles per hour.

Crop types differ considerably in their pollution potential. Field crops as a group are about two times more polluting than the prunings from orchard crops. The method of ignition also has an important effect. Head firing produces two to three or even four times more particulate matter than does back firing. By head fire, we mean burning with the wind or up-slope. A back fire is defined as burning against the wind or down-slope. Back firing is more expensive because more time is required to burn a given acreage. Another important consideration is fuel moisture; the drier the fuel, the cleaner the fire. Thus where burning needs to be done, the farmer does have some management choices for reducing pollution.

ISSUES AFFECTING THE AVAILABILITY AND PRICE OF LAND FOR AGRICULTURE

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This paper first reviews some data relating to agricultural land use nationally and then discusses the huge increases in land prices that have occurred in recent years and some of the implications for agriculture. The final section evaluates the need for public policy to preserve prime lands for agricultural use.

Land Availability for Agricultural Purposes

The cropland base in the United States is approximately 385,000,000 acres.[1/] An average of 1.3 million new acres enters this base annually via land clearing, irrigation and drainage development, and cropping land previously held out of production. On the other hand, an average of 2.7 million acres of cropland is lost to non-agricultural uses each year. Thus, there is a net loss of 1.4 million acres, or about one-third of one percent, of the national base.

Even this very small figure, however, may exaggerate the seriousness of this loss of cropland from a national perspective. The soil conservation service has estimated[2/] that there are 266 million acres (69% of the present base of potentially tillable land) in pasture, forest and other uses which could be added to the cropland base if it were economically feasible or socially desirable to do so. One view, therefore, is that the land base is quite adequate to provide for the agricultural needs in the United States for the rest of the twentieth century at least.[3/]

Other historical figures tend to support this optimistic view. The total land area devoted to crops in the United States has been reasonably constant since World War II. The 1949 cropland acreage was 387,000,000 --- a fifty year high. By 1969 this figure had dropped to 333,000,000 acreas but rose again to an estimated 367,000,000 acres in 1976.

Throughout the 1950's and 1960's, prices of most basic farm commodities in the United States were supported above world market levels. Various land set aside policies were invoked to help limit the supply of farm products in order to support prices at pegged levels. From 37 million to 65 million acres were kept out of production during the years 1961-1972. This acreage is fourteen to twenty-four times the annual loss of cropland to other uses. By 1976, however, most of this set aside acreage had been returned to crop production under the impetus of favorable farm prices, particularly from 1972 to 1975.

By 1975, however, that old nemesis in our agricultural history called excess supply, had returned putting downward pressure on farm prices. The Carter administration and the congress have decided that, to keep price support costs at politically acceptable levels under the target prices announced in the 1977 farm act, supply must be curtailed by new land set aside programs: a 20 percent set aside for wheat and 10 percent for the feed grains.

The evidence is abundantly clear that this nation has never had a serious shortage of land available for agricultural use. To the contrary, given our programs to support incomes in the agricultural sector and to stabilize prices by establishing price support

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1/ Cotner, Melvin G. "Land Use Policy and Agriculture: A National Perspective" ERS-630, Economic Research Service, USDA (July 1976).

2/ Ibid page 3.

3/ This is essentially the view taken by O. Krause and D. Hair, "Trends in Land Use and Competition for Land to Produce Food and Fiber" Perspectives on Prime Lands, USDA (July 1975) pp. 1-26.

floors, incentives have been required to induce farmers to keep land out of production. If conditions were somehow reversed and agricultural production became highly profitable, and if the government had no set aside policy, there seems to be an adequate reserve of land waiting to be brought into production. Further technical advance is bound to increase land productivity and greater doses of capital, labor and management could also increase yields substantially and stretch the effective supply of land. I simply cannot find compelling evidence to support the view that our nation faces a critical problem in the foreseeable future in shortages of agricultural land.

The Price of Agricultural Land

A more interesting question, to the economist at least, is the price of agricultural land. After all, it is the price that represents the per acre wealth that land owners have tied up in land and that farmers must pay if they are to acquire it for productive purposes.

Columns 6 and 7 of Table 1 report the real per acre values for agricultural land in 1970 dollars and for that land plus improvements respectively for the post World War II years. Both series have approximately tripled over the period.

The tremendous profitability of holding agricultural land for capital gains through this period is shown in Table 2. The numbers in columns 3 and 4 indicate the average real rates of return from holding land through the period specified in Column 1. For example, if a typical parcel of agricultural land was purchased in 1946, held until 1975 and then sold, the average real rate of return on the original land price would have been 3.25 percent per year. Unfortunately, no data are available on the variances on these returns, either cross-sectionally or over time, except for some state data to which I will later refer.

It needs to be emphasized that these are real returns corrected for inflation. As such they are very high compared with real returns from holding other capital assets in the American economy. Average real returns to capital in the economy as a whole have averaged just under two percent over this century.[4/] Another significant point is that these yields represent real capital gains just from holding land. The annual rents obtainable from using land in productive pursuits have not been included in these returns except as they have been capitalized into the value of land. Thus, there is no double counting.

Besides the size of these real rates of return, two other points are worthy of mention. The first is that the real rates of return to land only are consistently higher than those to land plus improvements regardless of the period considered. This corroborates the point made earlier that the real returns to land are higher than the real returns to capital prevailing in the economy as a whole. The other significant point is the tremendous increase in the real rates of return in the last five year period (1971-75) compared with the rest of the total period. Had 1976 data been added to this period, the results would probably have been even more startling. I will have more to say about this period later.

The steady post-World War II rise in the real value of agricultural land is one of the most puzzling phenomena of our times. Numerous explanations have been offered and some of them are indeed plausible a priori.[5/] The most obvious reason for increasing real land prices was the expected increases in net income accruing to landowners in agriculture. Net income, however, is a function of both the returns and costs of agricultural production and both might be related to land price increases.

Let us see what has been occurring to prices received and prices paid by farmers. Is it reasonable to infer that increases in real land values are attributable to increasing real farm output prices? The composite index of real prices of all farm products at the farm gate is shown in column 2 of Table 1 and the corresponding index for real crop prices only may be found in column 3. Since World War II, the year of the highest relative farm product prices and crop prices was 1947 when the indices stood at 184 and 216 respectively. By 1955, the crop index had fallen to 155, by 1960 to 132, and

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4/ Tatom, John A., "The Welfare Cost of Inflation" Federal Reserve Bank of St. Louis Review, Vol. 58, No. 11, (November 1976), p. 13.

by 1965 to 128. The low came in 1970, the base year, with a value of 100. The 1972 figure rose to 105 and by 1973 had jumped to 151, about the same as in 1956. By 1974 the index was up even further to 176 but fell off sharply by 1976 to 136. All farm prices show similar patterns of movement but with less amplitude. Thus, although relative farm product prices rose from 1970-74, they are now declining once again and are far below what they were in the early post-World War II period. Only some catastrophic events on a worldwide scale that sharply reduced food production could increase real farm product prices to levels of the 1940's and 1950's in the near future.

Comparing the indices of real farmland prices and prices received by farmers reveals a strong negative correlation, with the exception of the short period 1972-74. It is not plausible, therefore, to impute rising land values to favorable agricultural prices alone. Of course, farm revenues are the product of prices and output. Changes in output per unit of input will be related to land prices shortly.

The other component in net income is cost, the product of input prices and input quantities. Could it be that net incomes have risen in the face of declining output prices because either productivity has increased or input prices have declined more than output prices? In either case, per unit costs probably would have declined.

Consider the question of input prices first. A composite of prices paid by farmers for nonland production inputs in real terms is found in column 4 of Table 1. This series is much steadier than the two output price series discussed above, although similar in direction. The high value occurred in 1951 and the low in 1970 and 1971. There was a declining trend through the 1950's and the 1960's and a sharp rise after 1972. The figures for 1974-75-76 were 121-121-124 respectively. One must go back so far as 1954 to find the numbers so high as 124.

A comparison of prices received and prices paid reveals that the relative prices received by farmers dropped much faster before 1970 than prices paid. During the early 1970's, prices received rose faster but by 1975 prices paid had caught up. This evidence suggests that increasing land values may not be attributed simply to farm output prices rising relative to farm input prices. Indeed, the terms of trade have been steadily worsening for agriculture throughout most of the post-World War II period except for a couple of years after 1972.

If the explanation for rising land values cannot be found in prices of outputs and inputs, perhaps it can be found in the productivity of the inputs. The USDA average index of crop production per acre of cropland, one measure of productivity change, appears in column 5 of Table 1. There is little change in the index from the mid-1940's to the mid-1950's. From the mid-1950's onward, however, there is an upward trend until 1972, when an apparent leveling off occurred. It is too early to tell whether the series will continue its historical two-decade upward climb. Much depends on the quantity of private and public investment in agricultural research and extension, the weather, pest control, and the availability and prices of critical inputs such as energy to agriculture. Also, regulations imposed on agriculture in the form of labor, health and safety, and

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5/ Perhaps the best study in this direction is by Reynolds, John E. and John F. Timmons, FACTORS AFFECTING FARMLAND VALUES IN THE UNITED STATES, Iowa State Agriculture and Home Economist Experiment Station Research Bulletin 566 (Ames 1969). Independent variables regress on a time series of agricultural land values and signs of the regression coefficients were: 1. Expected net farm income (positive), 2. Government farm program payments (positive), 3. Expected capital gains (positive), 4. Technological advance (positive), 5. Farm enlargement (positive), 6. The number of voluntary transfers of farmland (negative), and 7. An increasing demand for land from a growing population (positive). It appears, however, that the high R^2's and some significant regression coefficients might have resulted from a failure to deflate the various monetary series by a price level index. The steady inflationary trends over the period may have caused an upward movement in all the nominal values of the various series and thus distorted their real causal significance.

environmental policies are important determinants of input productivity. In any case, the index series of productivity and the series of real land value tend to move together through time.

Let us now consider net farm income directly. The relationship between land prices and net farm income was studied by Scofield in 1964.6/ He calculated the secular trend in net farm income and the ratio of per acre values of farm real estate to per acre net farm income. Net farm income was defined as per acre revenues minus per acre nonland cost, where land included the value of capital improvements. The ratio was approximately six for the late 1930's, primarily because net farm income was very low. The ratio dropped to approximately four for 1946-47, a period when farm income rose but land prices did not respond proportionately. From 1948 to the early 1960's there was a steady rise in the ratio from about four to nearly ten. I made an analogous calculation for 1975 and the ratio was 14.5. I am predicting that the 1976 ratio will be even higher when the data are finally in, since net farm income was down somewhat from 1975 but land prices continued upward.

The sharp rise in this ratio implies that either farmers are expecting continuing increases in net income that will be capitalized into higher land values or alternatively, other variables are explaining the rise in the ratio. The latter explanation is implied mildly by other Scofield results. He estimates a cross-sectional equation that regresses the log of per acre net farm income for each state, the independent variable, on the log of per acre farm real estate value for each state, the dependent variable. Scofield's estimates are for three periods: the average for 1936-1940, 1951-53, and for 1961-63 (see Table 3). I made the same estimates for the period 1972-75. Each of the slope coefficients (the b's) is statistically significant at the one percent probability level, suggesting that changes in land values are associated with changes in net farm income for all periods. Also, the data show some tendency for the explanatory power of net farm income as reflected in the R^2's to fall after 1951-53. Apparently other variables not specified in the two variable models are increasingly important. The same conclusion is implied by the falling b's (the elasticity indicating the percent change in land values associated with the one percent change in net farm income) after 1951-53. The significant conclusion that emerges from these data is that net farm income accounts for nearly 80 percent of the cross-sectional variation among states in per acre land value and is therefore probably the critical factor in accounting for the secular rise in real land values. It is obvious that the profitability of agriculture will continue to play a crucial role in agriculture's ability to compete for land.

It is highly instructive to see where the large increases in land values from November 1975 to November 1976 were occurring. The map (Chart 1) tells much of the story. It is the grain states where the largest increases occurred over this period: Illinois, Iowa, Ohio, Indiana, Nebraska, Minnesota, Wisconsin and Missouri. The grains are our most important export crops. This ties the increase in land values to our role in the world market, to which I will return later.

Two implications are suggested by these data:

1) Land conversion demand may not be so important in raising land prices as is alleged. The highly urbanized states are not those where high land-price increases occurred. There is one significant caveat that should be stated, however. One block of the low-increase group -- Hawaii, California, New York, New Jersey, New England, etc. -- are those states where there has been much discussion about restrictions on free market transfers of agricultural land to other uses. If land cannot be freely transferred, its value as a speculative asset will be diminished. These restrictions take the form of agricultural zoning and various other devices to be discussed later.

2) There was an abrupt shift in expectations for higher net incomes in agriculture in the early 1970's that soon became translated into higher land prices. It is not difficult to see why a new era for agriculture was expected. Each of the following factors could be elaborated at great length:

6/ Scofield, William H. "Land Prices and Farm Income Relationships" Agricultural Finance Review, Vol. 25, August 1964.

a) The dollar devaluations in December 1971 and February 1972 made American exports more attractive and in particular made our grains more competitive in world markets. There have been seven successive years now of increases in agricultural exports. For the past four years agricultural exports have gone over 20 billion dollars per year, which is over half of what we normally spend for imported oil. It has been estimated by the Department of Agriculture that fully one-third of our present agricultural acreage is being devoted to crops which are later exported.

b) Rising per capita incomes in countries around the world and high income elasticities for food caused the demand curve for our products to shift to the right.

c) Bad monsoon weather in South and East Asia during the period 1972 and 1973 increased our exports to those areas.

d) The celebrated crop failures in the USSR had an impact on grain prices that got worldwide attention.

e) The anchovies off the coast of Peru shifted their location and this had an effect on world supplies and prices of fertilizer.

f) The great wave of pessimistic forecasts of world hunger by demographers, biologists, and agriculturalists, persuaded many, including America's farmers, that the world was entering a new era of increasing relative food prices and increased profitability of agricultural production.

g) In response to higher world prices and low reserve stocks of grain, there was a loosening of production controls on U.S. farmers.

h) Governmental policies in many countries, such as those in the European Economic Community and all the East Bloc countries, prevented their internal food prices from rising. This meant that consumers did not curtail their demands and producers did not increase their supply as would have occurred had prices been permitted to rise. The effect was to shift the main burden of supply and price instability to the international grain markets and the exporters of grain.

i) Finally, the income tax and general inflation policies that were pursued in this country over these years provided incentives for investment in agriculture and speculation in land.

How important each of these factors is in explaining the recent increase in land prices has yet to be determined. We have just initiated a research project to assess quantitatively the effect of these factors and, in a year or two, we hope to be able to say something more definitive than we can today. We already know, however, that the predictions which were made in the early 1970's have not been valid.

In their world hunger study7/ my California colleagues suggest why the expectations established in 1973 and 1974 giving rise to large increases in land values may have been too optimistic as follows:

1) There is general but not complete consensus that the world's population food balance is not undergoing a fundamental transformation toward chronic food shortages. Market surpluses will recur in the major producing countries in the world, and particularly in North America.

2) Rapidly expanding world fertilizer plant capacity has significantly lessened the fertilizer price and supply problems that peaked about two years ago (1972).

7/ Carter, Harold O. "World and U.S. Food Trends: A Current Perspective for Policy" Contemporary Economic Problems, American Enterprise Institute, Washington, 1976, pp. 293-322.

3) The agricultural productive capacity of the United States is basically strong and there is potential for expansion in the resource base and for continued productivity growth.

4) The real price of grain will remain roughly constant for a few years and then likely will begin to decline again.

In the case of point 4) my colleagues were too pessimistic. The high grain price did not last as long as anticipated. Except for soybeans, those grain prices are down very substantially from their peaks in the early 70's and surpluses of wheat, feed grains, rice, and cotton are building up.

The California analysis assumed a constant real world price for oil and no sustained changes in weather patterns. As everyone knows, the price of oil has risen precipitously. The effects on agricultural production have not been perceptible, however, as the production of food in the world has been at record levels in 1975, 1976 and it appears 1977. Also, the California study assumed that investment in agricultural research and development in the United States would accelerate. This is beginning to occur and the impact on national food production will be positive in the years to come.

What do I conclude about the real significance of rising land prices? I do not believe that they necessarily reflect a real shortage of agricultural land in any productivity sense. Rather, they are attributable to the rising expectations for profitable food production that were established in the early 1970's. These expectations are not likely to be borne out as we move on through the 1970's and the 1980's. If I am correct, the rate of increase of land prices will surely fall, and prices might well fall in absolute terms as well. Already there are reports of declining land prices coming from the Midwest where recent increases have been greatest.

Other asset markets run in cycles. These cycles have more amplitude than the basic economic forces underneath. The stock market is a good example. Speculative fervor causes stock prices to go beyond those warranted by levels of profit flows and vice versa on the downside. It is quite significant that the upward trends in land prices discussed above have lasted since the 1930's, a very long time as cycles go. This may have suggested to speculators that there were few risks in land speculation. This is the stuff of which speculative "bubbles" are made. The effect would be to increase the size of the bubble and to greatly intensify the seriousness of the situation if and when it bursts. To make matters worse, the process feeds on itself in a spiraling way. Higher priced land increases net worth, which increases borrowing capability. This stimulates the demand for land and raises land prices. The cycle is then repeated as farm enlargement occurs. Some unpublished data out of the USDA suggest that one-third of American farmers that have loans with the government and with the commercial banks are in financial stress in terms of repaying those loans. Much of this condition must be attributable to the very high land prices which farmers have been paying for the last few years.

One wonders if there are historical parallels of this phenomenon. A striking example occurred in the early 1900's (see Table 4). There was a very rapid escalation in farm product prices during the World War I years, 1915-1919, followed by a decrease after 1920. The index of per acre land and building prices indicates that they lagged behind product price increases. There was a very rapid increase in land prices in 1919-1920, and then the bubble burst. By 1933, the index had fallen to 55.3, less than half the level in 1920.

Clearly the 1970's are not the 1920's. The federal government is immensely more powerful, richer, and more Big Brotherly than it was then. Private financial institutions are much stronger and better protected by federal insurance. Still, the current cash flow situation in agriculture could be serious and may be more so if speculation gets further out of hand.

Prime Land Preservation

Another complex issue of current interest is prime land preservation. Several state legislatures, including California's, are considering enactment of tight zoning laws to preserve high productivity land for agricultural use. The tax preferential policies and other planning devices designed to protect agricultural lands from conversion to other uses have not been very effective.[8] Some of our best agricultural land continues to be converted to expanding urbanization, transport, utility easements, and for a variety of public purposes. So it is argued by those who advocate zoning for agricultural land that more drastic measures are now needed to stop this avalanche before serious agricultural land shortages occur.

Of course, if social action is needed to retain prime land and agricultural use, the implication is that the land market cannot efficiently allocate land resources among competing uses. Under the tax preference schemes use changes could still occur through the market if value differentials were great enough to offset the production cost advantage created by the tax preference. The crux of the proposed prime land preservation legislation is quite different; it removes the land allocation decisions from the market entirely by using productivity criteria to qualify land for preservation and by granting the power for exemptions and use changes to designated boards.

What society appears to get in the action of preserving agricultural land are at least four joint products (benefits):

1) "Sufficient" food and fiber to meet the nutritional requirements of a growing national and world population

2) Local economic benefits that derive from a viable agricultural industry

3) Open space and other environmental amenities that accrue chiefly to urban residents, and

4) More efficient orderly and fiscally sound urban development.

Given that these are the joint benefits that will hopefully be achieved by retaining high productivity land in agriculture, what is the rationale for extra market social action?

Market Failure and Prime Land Retention

So long as product and factor markets are perfectly competitive, goods are private as contrasted with collective, and no externalities exist, it is generally conceded by economists that the free market will allocate the socially optimal quantity of land to various competing uses. Thus, if the market is removed from the allocation task and is replaced by essentially non-market allocation criteria as is proposed by the prime land preservation legislation, some rationale should be offered. In addition, the consequences in terms of economic efficiency and equity should be carefully evaluated.[9]

Space limitations will not provide a full development of classes of market failure that may justify public intervention with the land market. Rather the approach utilized here will be to discuss the four joint benefits alleged to be significant in prime land retention and see if there are elements of market failure that justify the removal of the land market from allocation decisions.

It is difficult to see why the market will not allocate sufficient land to food and fiber production. The food and fiber sector of the economy is as competitive as any other, and food and fiber prices adjust rapidly to changing conditions in supply and demand. The enormous increases in agricultural land prices in the last five years have been due principally to expectations for higher food and fiber prices at the farm gate as discussed above. If further increases are expected there is nothing inherent in the land market that would prevent these expectations from yielding even higher land prices. The more productive the land, the higher the agricultural land price can be expected to be and the more competitive agriculture will be for land vis a vis other land uses. The

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8/ See Hansen, David E. and Seymour I. Schwartz "Prime Land Preservation: The California Land Conservation Act" Journal of Soil & Water Conservation 31 (1976): 180-208.

9/ Much of this argument is taken from Gardner, B. Delworth, The Economics of Agricultural Land Preservation, Paper presented at the meeting of the American Agricultural Economics Association, San Diego, August 4, 1977.

greater the comparative advantage of American agriculture and the fewer the impediments to free world trade in agricultural commodities, the greater will be the demand facing our producers, the higher the profitability of producing food, and the stronger the competitive position of agricultural producers who compete for prime land.

The collective good and externality arguments do not seem very relevant when applied to food and fiber. These products meet all of the requirements of private goods and significant external effects are not obvious in consumption. There may be external diseconomies in production of food and fiber (such as the use of chemicals) but this would suggest too much effort in production -- not too little.

Decision makers across the spectrum of agriculture -- such as farm operators, processors, farm suppliers, transporters, financial firms, university professors in agricultural fields, and government agency personnel -- have obvious stakes in a viable and stable industry. Land owners are directly affected in a unique way by the prime land retention issue. If land is immobilized in agricultural use, they forfeit the direct wealth gains in price appreciation that would have occurred with the possibility of changing use in a free market. The others listed above are affected more indirectly. The wealth impacts, however, could be substantial for them also -- positive or negative. Conceptually, these indirect impacts are identical to secondary benefits and costs in traditional benefit cost analysis. In addition, these effects are primarily pecuniary as contrasted with technological and thus they are fully reflected in the market prices of the services rendered. As such, they qualify neither as collective goods nor relevant externalities in justifying interference with the land market.

Some might argue that income and wealth differences among regions may justify prime land retention in order to prop up the dominant local industry -- agriculture. The argument is thin, however, as related to the secondary beneficiaries listed above because they tend not to be low income people. It may apply to some immobile farm workers who may benefit if local land is left in agriculture.

Many of these same issues are applicable to producing a more efficient, orderly, and fiscally sound urban development by agricultural zoning. If prime land cannot be developed for urban purposes, demand will shift to parcels which are not so zoned thus conferring wealth gains on the owners of these parcels. Whether the result is a more or less efficient urban development is far from clear, however. It depends on where these parcels are, how efficient they are at producing urban amenities, what the costs are of bringing public utilities and transport to these parcels, etc. It is not obvious in principle that urban "leapfrogging" will be reduced over what the free market would have produced. Much would depend on the criteria utilized to zone agricultural land, the number of zoning variances granted and the availability of soil types and other land classification data.

Finally, there is the case where market failure is most apparent -- the creation of open space and environmental amenities. These benefits obviously meet the criteria for collective goods and since there are no market signals there is little evidence available as to how much these amenities are worth. In any case, in principle at least the market will not provide the optimal quantity of these amenities and there may be some justification for social action to remedy this market failure.

Efficiency and Equity Implications

It is significant that both the land capability classification system of the Soil Conservation Service and the Storie index, which in most states are to be utilized to designate prime land parcels, are strictly oriented toward physical productivity. Location plays no role whatever. Because of the point made earlier that agricultural productivity may not be the only purpose for land retention in agriculture or even the major one, criteria that do not include location factors may be quite inefficient in producing desired results. Enhancing environmental amenities, removing competition for urban land parcels, and preventing urban sprawl are all tied up in the location of the land parcels affected. Urban people who want these joint products of land retention may well be frustrated and disappointed in the results of the land preservation scheme that retains land in agricultural use based only on agricultural productivity criteria.

It must always be remembered that there is no good substitute for the market in providing signals in the form of prices that reflect relative scarcity of resources and relative values of these resources in alternative uses. A set of firm property rights is the institution that permits the market to serve this function efficiently. When property rights are altered -- such as would be the case if land disposition is restricted -- the signals are distorted, and the market does not work efficiently. If society really has a scarcity of agricultural land and food and fiber prices are not artificially controlled at lower than equilibrium levels, the land market will serve perfectly well to reveal its scarcity. If this effective instrument for revealing scarcity is replaced by the prime land retention schemes proposed where inadequate economic or political criteria will dictate resource allocation, there will be no reliable way of knowing whether agricultural land is becoming scarcer or more plentiful.

Another common allegation is that in investment decisions the market is short-sighted compared with political processes. In fact, do the actors operating in the market have a bias toward the present that is socially inefficient. The land "speculator" is that bad guy who makes his living predicting the future more accurately than the rest of us. He has an incentive to do his job well and market prices reflect his anticipations of future scarcity. What reasons can be advanced for believing that a part time agricultural board member or even a career planner, to say nothing of a legislator elected for two years, can do a better job of predicting the future.

Because the market is an institution where preferences can be freely expressed, although these preferences are constrained by limits on purchasing power, there is always some uncertainty associated with market allocation. There may be even more uncertainty connected with government allocation, however, as politicians and even agency bureaucrats are notorious for changing their minds. Although the uncertainty question is far from clear there will almost surely be more freedom of choice in the market and better information of foregone alternatives.

It is true as suggested above that the market may not provide the optimal quantity of the collective good -- open space -- but neither will the prime land retention schemes. They preserve land on the basis of agricultural productivity and there may or may not be a good match between high productivity agricultural lands and open space for urban recreators. Given that open space is partially a joint product with agricultural use, it is an empirical question whether the land market or zoning based on agricultural productivity criteria will provide more socially optimal quantities of open space. If there are critical shortages of open space then a sensible and efficient solution would seem to call for open space selection criteria and either zoning on that basis or public acquisition of the requisite lands in the market.

If it is granted, contrary to my belief, that there are public interests to be served in supplying open spaces and feeding the world's people by prime land retention, then the equity issue boils down to creating these benefits by imposing a wealth loss on the owners of prime agricultural land by immobilizing the land in that use and thus preventing land use shifts at higher prices. Thus, unless compensation is given, these land owners absorb losses in order to provide the collective goods enjoyed by society as a whole.

Another equity issue that is often overlooked is that the purchasers of land for non-agricultural uses will be required to pay higher prices for those land parcels than they would be required to pay in the absence of a land preservation policy. If part of the land supply is removed by governmental action from the market the inevitable consequence is a price rise for those parcels which remain available to the market. It is a bit odd, therefore, that we do not see urban consumers lobbying against prime agricultural land retention.

Even though there do seem to be devices such as zoning by eminent domain and transfer of development rights that can mitigate the equity problem there has been no attempt to incorporate them in the proposed legislation and there is even a conspicuous absence of any discussion of them. What is perhaps even more significant, there is not even any explicit recognition that an equity problem exists at all.

Summary and Conclusions

In the way of summary:

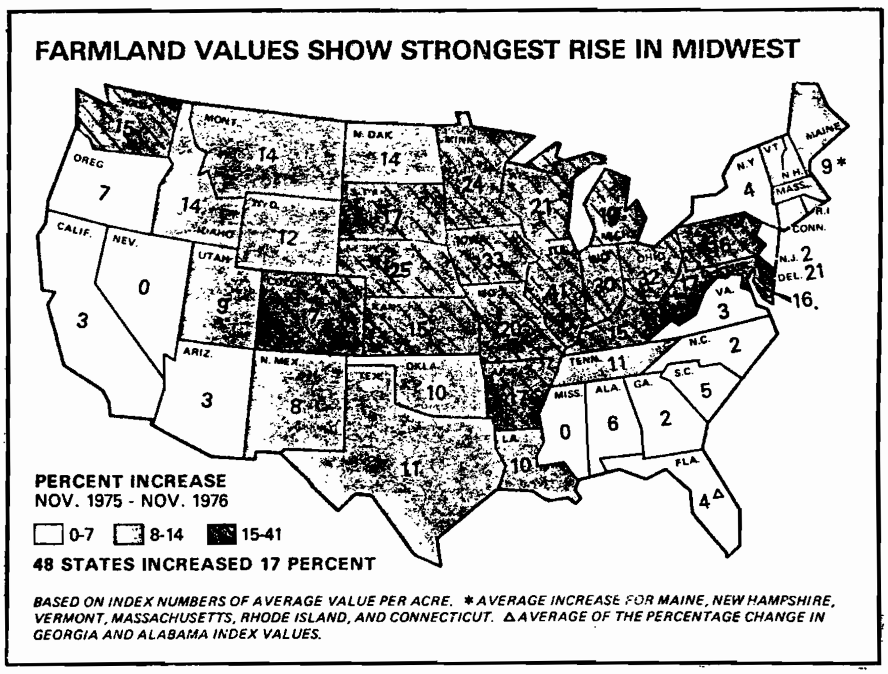
1) It is clear that physical/biological possibilities for increasing food production around the world are enormous, especially in our own country.

2) If food were to become increasingly scarce food prices would rise if they are free to do so. Investment in producing food would rise and food output would increase.

3) Society can be expected to increase resources for research and extension if food becomes relatively scarcer and this would have a substantial long run output increasing effect.

Given the above I am optimistic except for three worries which I will now summarize. The explosion of land prices has some ominous possibilities. What we might do about them is far from clear to me, however. Secondly, a serious problem in my opinion is the unwillingness of the government to let the free market set prices to serve as signals for resource allocation. The most obvious example is the threat of further government tinkering with the land market. In addition, the United States government has set target prices for basic agricultural commodities that almost guarantees surplus production in the grains and cotton. In a very short period of time we could be back in the situation of the 1950's and 1960's with expensive surplus disposal programs. Thirdly, exogenous restrictions on agricultural production are becoming evermore numerous and onerous. These restrictions are ostensibly invoked to protect the environment and to maintain health and safety of farm operators and workers.10/ Of course, there are compelling reasons for government policy to protect the environment and the safety of farm workers but it is not often realized that these policies are costing agriculture a good deal in terms of efficiency without at the same time mitigating our real environmental problems. It is time for a tough minded benefit-cost assessment to determine if these restrictions on agricultural producers are justified.

CHART 1



10/ These policies are discussed in Gardner, B. Delworth and John A Zivnuska "Public Policies Affecting Land Devoted to Agriculture and Forests" Paper presented at the annual meeting of the American Academy of Science, Denver, Colorado, February 1977.

TABLE 2

Average Real Rates of Return Yielded by Holding Agricultural Land, 1946-1975

Period	Years	Land Only	Land and improvements
1	2	3	4
		percent	
1946-1975	30	3.25	2.84
1951-1975	25	3.73	3.09
1956-1975	20	4.03	3.42
1961-1975	15	3.84	3.37
1966-1975	10	3.52	3.13
1971 1975	5	6.13	6.00

TABLE 3

Regression Results Relating Land Values and Net Farm Income Averages for 1936-1940, 1951-1953, 1961-1963, and 1972-1975

	Coefficient			
Years	R^2	a	b	Standard error of b
1936-1940	.833	.899	.838	(.059)
1951-1953	.890	.952	.952	(.045)
1961-1963	.865	.262	.750	(.046)
1972-1975*	.790	1.283	.730	(.058)

*Note: The logs of 1975 farm real estate values per acre were regressed on the logs of the 1972-1975 average net farm income per acre.

TABLE 4

Farm Prices and Land Value Indexes, 1911-1922

Year	Farm product price index (1924=100)	Index of average value per acre of land and buildings (1924=100)
1911	66.8	74.9
1912	72.6	76.9
1913	71.5	78.6
1914	71.2	80.2
1915	71.5	79.6
1916	84.4	84.2
1917	129.0	89.9
1918	148.0	97.9
1919	157.6	106.0
1920	150.7	127.8
1921	88.4	119.4
1922	93.8	105.6
1933		55.3

Source: Historical Statistics of the United States, Colonial Times to 1970, Part I, U.S. Department of Commerce, Bureau of the Census, 1975.

SOME ALTERNATIVES IN WATER SUPPLY AND USE FOR CALIFORNIA'S AGRICULTURE

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The story of the past two years in California has been WATER:

* the lack of it
* the need to conserve it
* the need to share it
* the need to store it
* the need to control it
* the need to transport or divert it
* the need to reclaim it
* the need to dilute wastes and repel salts in delta
* the need to generate power with it
* the need to protect and preserve natural waterways
* the need to protect and preserve fish and wildlife
* the need to develop more water recreation areas.

Let's begin by briefly reviewing California's water situation.

In normal years, California is blessed with a deep mantle of snow in the Sierra extending well down the slopes to 4000 ft. and often below. In winter 1976-77, snow was shallow and limited to upper elevations with total water content about 20% of normal on typical Central California watersheds. Fortunately, California Water Projects (CVP, SWP and others), by providing carryover storage, got us through 1976 with few shortages in areas served by reservoirs. By beginning of summer 1977, carryover was down.

Pardee Reservoir (serving EBMUD), very low
Nicasio Reservoir (serving Marin), essentially dry.

The small carryover forced mandatory rationing and considerable disruption in many cities. Some smaller reservoirs serving agriculture were dry (Indian Valley) at beginning of 1977 irrigation season. Large reservoirs, key units in the CVP and SWP, continued to deliver water into 1977, although deliveries were restricted.

Water year 1977	Impaired inflows to Sac. Valley Reservoirs	3.9 MAF
	Withdrawn from storage (Sac. Valley & Trinity)	3.5
	Total releases by SWP and CVP (excluding Friant)	7.4

Thus, contrary to the well-publicized statements of highly placed state and federal officials dismissing dams as making little contribution to combatting drought, we see that in 1977 - even though substantially drawn down in the previous 1976 drought year - the CVP and SWP reservoirs approximately doubled the water available in water year 1977.

As the result of withdrawing stored water in 1977, major reservoirs were at historic lows by September 30, 1977: Shasta (22% of 10-year average), Oroville (37%), and Folsom (22%). Not only were users in water service areas cut in use, but boating was curtailed and boats were left high and dry. Other water-related recreation was hard hit.

Facing this bleak picture of meager water supplies last fall, water agencies prepared contingency plans which laid out arrangements for allocating the very limited supplies expected to be available between types of use and areas of use. This called for difficult decisions which would have created substantial unhappiness if conditions had forced their implementation.

For example, the U.S. Bureau of Reclamation prepared eight scenarios or conditions assuming different levels of inflow. Condition 8, in December, was considered as the probably worst case where inflow would approximate the 1977 inflow. This low inflow coupled with low carryover and the need to provide some carryover into 1979 should another dry year occur, called for limiting Sacramento River prior water rights holders to 75% of normal deliveries, M & I users (largely Contra Costa County) to 25%, Mendota Pool water rights holders and other agriculture to zero deliveries. A very bleak picture!

DWR plans called for issuing monthly water supply projections based on a "rule curve", with deliveries quoted at 4 probability levels.

While these plans were being laid, a sign went up on the headquarters building of the Marin Municipal Water District suggesting "pray for rain", and others joined in prayers. Water for next year became a concern of all. A cartoon on the editorial page of the Sacramento Bee suggested replacing the usual Christmas stockings with water buckets.

Suddenly the rains came! Slowly at first, then as record rainfall occurred in Northern California, reservoir levels turned upward.

	Jan. 24	last year	10-yr. av.
Shasta	2.8	1.6	3.1
Oroville	1.9	1.6	2.9
Folsom	.6	.3	.6

Large spills are now occurring from Folsom to provide the required flood control space. Floods quickly developed along the Russian River, an area hard hit by drought, and minor overflows occurred in many areas.

Slowly the drought came to an apparent end, although some reservoirs such as Pine Flat remain low today and groundwater has been lowered about 6 - 10 ft. in many areas. Rationing was lifted, prompting the San Rafael paper to blossom out with the front page headline, "Everything's back to normal".

The rains have come. In many areas, rainfall set new records for January. BUT California's citizens, and especially those in agriculture, continue to face some very difficult problems in meeting future water supply and use alternatives.

The California Water Problem involves many facets, complexities, and alternatives. Solutions are made difficult because of strongly held and often very divergent viewpoints. All of us are affected by water; yet our interests are different. These differences become emotionally and politically escalated with many differences ending up in extensive litigation.

"Water may well become the most limiting resource to which Californians will have to adjust in the coming decade" - begins a draft report prepared by the Water Study Group of a Task Force set up by the University of California's Division of Agricultural Sciences last spring to study Critical Issues facing California Agriculture in the 1980's.

But, I suggest, the extent to which water will become limiting will depend upon the water policies California chooses to follow. Changing societal attitudes and lifestyles, together with the rise of environmental concerns and the conservation ethic, have changed California's approach to water development and use.

CALIFORNIA'S WATER DEVELOPMENT POLICIES

Until about five years ago, California water agencies, within realisitic constraints of engineering and economic feasibility, have sought to make water non-limiting for expansion of use by planning water developments to meet projected future water demands based on population projections and expected increases in water consumption for all purposes. As a result, in many parts of the state, decisions involving water use could be made on considerations other than water availability. But now, water is being viewed as a finite resource, and water use must be constrained to the present or only modestly increased supplies.

This shift in basic policy carries with it a whole host of new issues, trade-offs, and policy considerations. These have generally not been adequately researched. This should include exploration of both the short-term and long-term consequences in a fully objective manner, including direct and indirect effects, and using highly qualified and experienced interdisciplinary study groups. Such studies should be free of the political constraints which now limit the ability of state and federal agencies to undertake fully objective explorations, to array all alternatives, and also to analyze the numerous trade-offs which touch on many other resources and on all aspects of life.

New concerns, arising from today's societal attitudes, may be summarized:

Preserve wild and scenic rivers
Shun dams and interbasin transfers
Emphasize water conservation
Avoid water pollution
Save energy

Clearly, the future emphasis will not be on new water supplies, but on management of present supplies.

Water interacts with man and with all other living and non-living systems on this planet in myriad ways. It is a vital resource for which no substitute has been found to sustain our bodies, produce our food, provide an essential input to many industries, and shape our total environment.

THE WATER PROBLEM AND SOME CURRENT VIEWS

I have often said the problem with water is people. Water problems magnify rapidly with rising populations. As California's population has climbed to about 22 million, so have its water problems multiplied dramatically. Recent information indicates that in-migration to California is again turning up. Recently the State's Department of Finance reported that net births are increasing and deaths declining. Migration to California during 1977 was 190,000 persons. Commenting on projections that California will add 8 million more people by 2000, Governor Brown recently said: "The more jobs we create, the more immigrants come to the state to take them, and it is impossible to ever out-run that because of the mobility and quality of life."

As we seek to understand and develop solutions for California's water problems, we face strongly divergent views expressed by a wide range of interests speaking out of different backgrounds. The following few illustrations indicate some views which others feel are far out.

The UN Global Water Conference held March 1977 in Argentina stressed the need to deal with water as a single resource bringing our water problems into some kind of unitary perspective. The Conference pointed out that water "tends to be available in the wrong place, at the wrong time, or with the wrong quality". A writer in a recent issue of National Parks and Conservation Magazine (October 1977) points out that this expresses a common bias. This writer says: "it is not water that is out of order, out of place, but mankind". He continues, "Tampering with the order of nature (as we do with water projects) can be fraught with disaster, as we are discovering to our consternation and dismay. Better to change the order of our thinking and consider the wisdom of moving people instead of water - - ".

The paperback "The Unfinished Agenda" published in 1977 reports a broad environmental study sponsored by the Rockefeller Brothers Fund and contains many disturbing statements. Why is this report significant? For several related reasons. One is the diversity, influence, and generally good reputation of people involved. Another reason is that many of their proposals are already imbedded in various proposals, some of which are already pending in Congress. The following quoted material reflects the tone of this report.

"The whole water-supply problem is greatly compounded by continuing large water-engineering projects of the U. S. Army Corps of Engineers and the Bureau of Reclamation. All too often nowadays these are "pork-barrel" projects which diminish the overall resource (by enhancing evaporation from impoundments), destroy land, wildlife habitat, and recreational opportunities, while providing marginal or negative real net economic benefits. The federal government has for too long subsidized unwise, economically inefficient, and environmentally destructive water-engineering projects, which in turn have permitted and stimulated unwise settlement and development.

"In view of the critical role of water supplies in determining patterns of settlement, land use, energy supply, and industrialization, especially in the western United States, it is urgent that present water policies be reevaluated in the light of present-day conditions. Even the National Water Commission, which reported in 1973, failed to anticipate adequately the importance of water as a limiting resource, a factor now emerging in the mid-1970s. Although many of the Commission's recommendations are still valid and need implementation, major new initiatives are needed. We therefore recommend that:

* A new national commission be established to re-evaluate the problems of water supply, water allocation, and waste-water disposal, and to prepare a national water plan with specific consideration of its implications for industrial and agricultural development, population distribution and environmental impact. Pending the preparation of such a plan, large-scale new commitments of water or inter-basin transfers should be suspended.

* The general principle be adopted that users of water should pay the full costs of providing the supply (including external costs and realistic interest charges on capital investment).

* Water be recycled and re-used wherever economically feasible.

"As specific proposals to advance these general principles, we recommend that:

* The Bureau of Reclamation be abolished, and its ongoing construction projects suspended, pending their re-evaluation and incorporation into the National Water Plan.

* The Omnibus Rivers and Harbors Bill be replaced by a series of specific bills in which each proposed water construction project will be considered individually.

Currently authorized projects of the Corps of Engineers be re-examined for costs and benefits, using a realisitic value for the discount rate (and eliminating the "grandfather" clause which at present protects economically inefficient projects authorized long ago).

* Recharge of groundwater with the effluent from secondary sewage treatment plants be adopted as a general practice in areas where disposal elsewhere is leading to depletion of groundwater.

* Experiments be conducted with dual water systems (and dual pricing) in urban areas where water is scarce (using secondarily treated sewage for outdoor uses and new or tertially-treated water for drinking).

* Indian claims to water rights (whether by treaty or otherwise) be examined carefully on a case by case basis and, where valid, be reaffirmed and given priority over other claims.

* Special commissions be established to study the water needs of river valleys such as the Sacramento - San Joaquin, Imperial Valley, Colorado, and Rio Grande, where withdrawal of water from the rivers upstream has led to slow flow and salinization in the lower valleys or deltas.

* Universal (individual unit) metering be established in order to cut down on waste through leakage and to encourage conservation."

End of quoted section from report.

FEDERAL AND STATE WATER POLICIES

Change is occurring. President Carter, soon after taking office, announced the now famous water project "hit list" and his intention to call for a restudy of federal water policy. Task forces were formed in July 1977, and their draft report reflected much of the flavor of the previous highly controversial National Water Commission Report released in 1973. The present national study, being conducted by the Water Resources Council, is developing a number of policy reforms with much emphasis on water conservation (announced as the cornerstone of his new policy), full repayment of costs of any new project, and on numerous legal and institutional points.

In December 1977, the Water Resources Council put out a voluminous Water Resource Policy Study which is to be transmitted to the President in March and announced as the new National Water Policy by mid-summer.

At the State of California level, perceived societal attitudes are clearly reflected in substantially revised policies for the State's Department of Water Resources as issued by Director Robie in Spring 1976. In abbreviated form these are:

Use present sources before newly developed alternative sources
Water exchanges
Water conservation
Instream uses to be protected
Comply with water quality objectives
Full range approach to flood control
Consider all aspects - least expensive not necessarily selected.

Very active groups are urging that greater attention in the development and use of California water resources be directed to social issues. Some persons much concerned about these matters are labelling the actions called for by groups such as the National Land for People as moves to accomplish "major agrarian reform" indirectly by controlling water. The recently issued San Luis Task Force report deals with a number of these sensitive issues.

Some years ago, a group put out a brochure carrying on its front page the headline "Water to people, not to land". Although this may not make sense to an agriculturally oriented audience, it is seriously proposed by groups active in urban areas who see a cut in water to agriculture as the solution to California's future water supply problems. Such groups point out that reducing agricultural water use by only 10% would provide California with adequate water for years to come and avoid, what they term, the "destruction" of California's wild and scenic river resources.

WATER QUALITY

Time does not allow more than a mention of the obviously important problem of water quality and related concerns about controlling water quality degradation and pollution from municipal and industrial discharges and from agricultural run-off and other return flows. Federal law, primarily PL 92-500, has led to Basin Water Quality plans, controls on urban discharges and discharges from livestock operations, and to concerns about defining the Best Management Practices for agriculture.

These are some of the winds (almost gales) which are blowing today, making the water picture choppy, turbulent, and clearly unsettled.

Certainly this situation calls for increased efforts to discover facts; array alternatives with adequate attention to all direct and indirect effect; evaluate trade-offs of all kinds, both near the scene of action and at remote locations, including those which involve other resources such as air quality and energy; examine the social and economic aspects; determine the environmental consequences; etc.

Today's water situation is extremely fluid and full of tremendous challenges to experts in a host of disciplines. We need to develop much more information concerning the numerous aspects of the water problem and then integrate this information into an array of alternatives together with detailed analyses of all impacts - direct and indirect, short and long term - and also the numerous interactions involved. Such information is vital to public opinion-shapers and to planners and decision-makers at all levels of government. I suggest that this situation is a challenge to which the experienced, interdisciplinary, objective, and hopefully politically insulated faculties of academic institutions and personnel of other qualified organizations should address with vigor.

CALIFORNIA'S WATER PICTURE

Now let's turn to a brief summary of what is California's water picture. The situation has changed dramatically within one month! Less than eight days ago, the Sacramento Bee's editorial page cartoon (Jan. 18) showed in the upper part a poor fellow standing in a dusty field with the sun blazing crying out for water. The scene changes. In the lower panel is a fellow standing on his rooftop looking for land. Well, this is the way it's been. From drought to ample water and even to floods in a few areas.

What is California's water picture in a typical year?

The total statewide average annual precipitation is about 200 million acre feet. See Table 2. Of this, 65% is lost through evaporation and evapotranspiration from natural vegetation - forest, grasslands, etc. This leaves 71 million acre feet which appears as runoff in streams. Of this streamflow, 40% is in the north coastal area, 31% in the Sacramento River system, 9% in the San Joaquin River system, and about 20% scattered in the rest of the state. To this we should add 4.4 million acre feet imported from the Colorado River. About one fourth of the state's outflow or 18 million acre feet should be subtracted from the potential water supply because of legislation which places most of the north coast river system under protection of the wild and scenic river status.

Groundwater also must be considered. The total capacity of the groundwater basins underlying California has been very roughly estimated at about 1.3 billion acre feet. Some figures suggest that perhaps 143 million acre-feet may be classed as the usable basin. The overdraft occurring in typical years, largely in the San Joaquin Valley, has amounted to between 1.2 and 2 MAF annually.

It must be recognized that the numbers given in Table 1 and also in Tables 2 and 3 are only approximate. Various writings indicate a range of numbers. Time did not permit an analysis of the accuracy of those chosen, but they do suffice to indicate approximate magnitudes and illustrate problems to be faced in California's water supply and use picture.

What is the water use situation in California?

As given in Table 2, municipal and industrial users account for about 5 and agriculture 32 MAF, making a total of approximately 37 MAF as of the year 1974.

Water use projections are most important for planning. Based on four population alternatives, and four trade alternatives, the State Department of Water Resources in Bulletin 160-74 projected an increase from the present 37 MAF to between 41 and 46 MAF by 1990, depending upon the assumptions as to population fertility, in-migration, and agricultural use. By the year 2020, these projections rise to between 43 and 55 MAF. Population projections in Bulletin 160-74 have been criticized in recent years as being unrealistically high. However, in-migration has again increased, reaching 190,000 in 1977. The California Department of Finance in its "Provisional Projections of Calif. Counties to 2000" (Rept. 77 P-1, Series E-150, Aug. 1, 1970) now projects State's population to 29.3 million by 2000, reflecting an increase of 36% during the period 1976-2000.

To the above projections must be added some additional amounts which are difficult to quantify. These include releases to protect the water quality and the environment of the Delta and of San Francisco Bay which are called for under State Water Resources Control Board regulations, the Basin Water Quality Plans, and would be required under SB 346. The additional water required is still subject of debates. Also water is wanted for instream uses above the Delta. Prior to last 10-15 years very little, if any, water was reserved in most streams for fish and wildfowl needs in the granting of water rights and diversion permits. All water supplies available for annual diversion have, in most cases, been committed to other uses. The California Department of Fish and Game has applied to the SWRCB for a reservation of water for fish in certain streams. Denial of these applications has been appealed to the courts. If fish are to be granted a "water right", this would increase water needs by an uncertain amount.

Thus we have to add to the projections in Bul. 160-74 based on population levels and agricultural needs some unknown amounts arising out of the above environmentally related concerns.

How much new water yield is required?

A projected need of 46 MAF by the year 2000 would appear to be conservative in the light of the above ranges of projections for the year 1990 and 2020. This would be assuming the high level 1990 projections but allowing a 10 year slippage. This would assume that the State Water Project would deliver 4.2 MAF (assuming development of a water supply required to meet present contractual commitments) and that the USBR Central Valley Project would deliver 11 MAF (again assuming added development).

Satisfaction of the statewide water demand of 46 MAF would require development of at least an additional 6.2 MAF yield (46 MAF, less the present use of 37 MAF, less 2.8 M presently uncontracted but not necessarily uncommitted CVP yield). A total of approximately 8.2 MAF of new yield would be required if the present groundwater overdraft (1.4 MAF in S. J. Valley, plus 0.6 MAF in other areas) included in the present 37 MAF use is to be supplied in the future to avoid further groundwater mining with the resultant increases in costs, higher power requirements, and possibilities of land subsidence and degraded water quality.

What proposals are made to meet the projected deficit?

Four approaches are being advanced (see Table 3), one in Senate Bill 346 (Ayala) currently being debated before the Legislature. Features of this Bill are summarized in a useful special bulletin entitled "Key Elements - SB 346" recently issued by the Department of Water Resources. Features proposed in this Bill are estimated to provide about 2.7 MAF. This would be about 43% of a 6.2 MAF water demand, or 33% of the larger 8.2 MAF demand required to correct groundwater overdraft by the year 2000. These figures, taken from a recent summary prepared by the USBR, indicate a significant shortfall between the water development planned by SB 346 and past DWP projections of statewide water need by 2000. This is referred to by the Comptroller General of US in a recently issued report entitled "California Drought of 1976 and 1977 - - Extent, Damage and Governmental Response" which concludes with a chapter on water planning and development in California. The summary, carried on the cover, reads " ... it is questionable whether the water developments and proposals covered in the State water plan will meet projected water demands. GAO therefore recommends that the Federal and State Governments re-examine how to best meet future water demands."

In response, Director Robie pointed out that the water supply provisions of SB 346 were not intended to meet all the water needs referred to in DWR Bulletin 160-74. He goes on to write that other alternatives are under study to meet year 2000 water needs. These, he indicates, include conjunctive surface and groundwater management, waste water reclamation, and also institutional arrangements.

As indicated in Table 3, something over 1 MAF may be gained by conjunctive use operations, although currently planning for nearly one-half of this estimated gain through proposed operations in the Sacramento Valley has been suspended because of objections from area residents.

An additional approach is waste water recycling. Governor Brown last November established by Executive Order an Office of Water Recycling in SWRCB "to promote water reclamation in California to its fullest potential." New facilities are to be constructed to make available an additional .4 MAF/yr of reclaimed water by 1982. Attention is being directed to reclamation of wastewater from M & E users which is currently discharged to brackish and saline waters. Out of the estimated total potentially reclaimable M & I waste water discharge in 1975 of 1.4 MAF, approximately .2 is now being reclaimed. Potentially reclaimable is defined to exclude water lost in wastewater treatment plant, WW exceeding 1500 ppm TDS, and WW in areas where there is no feasible market for the reclaimed water. The total potentially reclaimable discharge by year 2000 is estimated at 2.5 MAF, with a possible achievable reclamation of 1 MAF.

Here, as in many other actions and proposals, there remain real questions which do not appear to have been adequately evaluated. These include the effects of WW on soils, plant production, human health, water quality in the surface and groundwaters receiving return flows, problems of treatment reliability, energy requirements, costs of distributing WW in separate systems, and costs of supplying equal amounts of water by other means. Use of WW for inland power plant cooling is also proposed. This possible use also leads to questions which will need investigation.

The fourth approach, water conservation, is expected to be the principal means of closing the gap between planned water supplies and projected uses.

The staunchest advocates of water conservation programs are saying that "we have run out of water" and accordingly all must now "cut use to fit supply".

In this connection it is significant to note that Secretary of Interior Andrus, in speaking to the National Water Conference held May 1977 in St. Louis, is reported to have said that "water conservation is needed more than (new) federal (water) projects to help prevent drought because dams, reservoirs, and canals do not create water." Andrus further said the drought has taught another important lesson "that people can, when they try, live with considerably less water than they are accustomed to."

Some estimate that M & I users in California could achieve a continuing conservation of about 1.5 MAF/yr as indicated in Table 3. However, at two recent National Science Foundation sponsored conferences on drought, questions were raised about the willingness of people to continue to live with less water if there are any alternatives. Some important questions. What are the social, economic, and environmental impacts of reducing water supplies to urban areas? What are the effects on quality of life including beauty of surroundings, air quality, etc.?

This brings us to the big question about water conservation in agriculture. There is the widely held view in California, especially among urban dwellers, that irrigation is wasteful user of water. They feel that surely irrigated agriculture, which diverts 85% of the state's developed water, can find ways to cut water use by at least a modest percentage. To many, a cut of 10% would seem reasonable and achievable. Were this to be done, it is argued, California could save about 3 MAF/yr which would essentially close the gap between proposed water supplies and previously projected water requirements.

What appear to be the realistic potentials for water conservation in California's irrigation agriculture? The Department of Water Resources issued in 1976 a special report (Bulletin 198) on Water Conservation in which estimates were made of water conservation potentials for both M & I users and for agricultural users in the various hydrologic basins of California. Table 4 is a condensed version of a concluding table which indicates that the potential water savings represent approximately 2.2% of the applied water on a statewide basis and less than 1% within the Central Valley.

In Table 3 I have indicated an estimated savings of .4 MAF as occurring above the Delta. This comes from a DWR statement of October 26, 1977 in which savings of .41 MAF in the Central Valley would be possible under dry-year conditions with an expenditure of $2.3 billion. These were considered to be the maximum savings possible regardless of expenditures. The DWR statement indicates savings would be accomplished by:

1. Lining major canals, ditches, and drains and substituting closed pipe, where practical, for open laterals, farm head ditches and drains to eliminate deep percolation losses, evaporation losses and use by native vegetation.

2. Installing drip irrigation in all young orchards and vineyards to reduce some of the evaporation losses compared to other irrigation methods.

3. Installing drip or sprinkler irrigation systems where appropriate, land leveling, and improving water system operation in association with irrigation management services to reduce deep percolation.

The DWR statement points out that the above efforts would reduce to a minimum all non-essential consumptive use losses and eliminate deep percolation of surface water supplies except that required for leaching accumulated salts. Properly, this statement recognizes that these measures would greatly reduce groundwater recharge. It points out that reductions in groundwater recharge are acceptable during dry years and are consistent with good conjunctive use practices but that the adoption of these water conservation measures would require providing special facilities to replace the lost capability for recharging groundwater during wet years. The statement concludes that only about .1 MAF of the .41 saved would actually reach the Delta.

These estimates of potential savings were far below those expected by environmentalists and some water planners. In fact, many continue to doubt such figures. These estimates are often cited by irrigation districts and farmers, who conclude that little can be done or should be attempted to improve water use efficiency in agriculture. Such arguments that little can be done are running into increasing criticism from non-agricultural people who feel that farmers are simply being defensive on this matter. Many agriculturists contribute to the perceived feeling of defensiveness by making statements only that it would be too costly for agriculture to improve irrigation practices. Unfortunately they do not mention the other real problems involved in changing irrigation systems and their operations. All concerned would be better served by a more analytical approach which would examine what happens to the water applied in irrigated agriculture and the extent to which the various losses of water are controllable in a practical sense.

While it is important to put into proper perspective the fact that water diverted in excess of crop needs in many cases is recoverable, and perhaps facilitates distribution of water to other users, such applications in excess of crop needs on successive farmer's fields may adversely affect society by increasing energy requirements from repeated pumping of the water, a greater loss of plant nutrients, and accelerated water quality degradation by leached plant nutrients as well as, in some cases, salts dissolved out of saline soils or parent materials from which the soils are derived.

Before leaving this matter of water conservation as a major method for balancing California's planned supplies and previously projected water needs, a potentially serious impact in case of future droughts should be recognized. At the two NSF-sponsored conferences on drought (referred to above), it was concluded, after thorough discussions, that dependence by water supply agencies on reducing normal demand by water conservation programs substantially increases future drought risks by reducing society's resiliency to respond to such a future emergency. The reason is clear. Balancing water supplies to a conservation-reduced demand means that the capability of society to cut its water use to respond to a new emergency has already been utilized. In other words, the "reserve" which might have been there under normal water use practices has already been committed. I believe this aspect of California's water planning deserves some careful study.

In the following sections brief mention will be made of four other topics which relate to water conservation.

REASONABLE AND UNREASONABLE USE OF WATER

The California State Water Resources Control Board and the Department of Water Resources are planning to adopt, under the authority of the Water Code in the State's Constitution, new regulations which will define certain practices as reasonable uses and others as unreasonable uses of water. The right to water is limited to such as shall be reasonably required.

Reasonable use generally allows application of sufficient water for evapotranspirational requirements so as to optimize production; for salt leaching using the best achievable technology economically feasible; for preventing crusting, salts or high temperature from inhibiting the germination and emergence of seedlings; for frost protection, cooling or pest management; and for livestock operations. Unreasonable use generally involves application of more water than is actually necessary to accomplish the above operations efficiently. Some examples where unreasonable use may be declared include the following from a November 1977 draft of the proposed regulations:

failure to adjust planted acres and crops to reliable water supply projections with respect to both quantity and quality

excessive irrigation soon after fertilizing with high levels of nitrogen

failure to recover runoff that is of usable quality where such would otherwise be wasted

failure to grade land, smooth checks, or utilize short, narrow irrigation checks and short furrows, along with tailwater recovery systems, where the absence of such practices has resulted in application of excessive water and where no other beneficial use, such as groundwater recharge, is being served

failure to repair leaks in canals, ditches, pipelines, distribution systems, or to replace orifices in sprinkler nozzles at such time as they cease to operate efficiently

operation of sprinkler systems during high wind conditions which results in a non-uniform or wasteful distribution of water

inflexible scheduling of farming operations and water deliveries which result in the distribution and application of water before it is actually needed

failure to keep irrigation canals and ditches, and areas between trees, vines, and other crops free of weeds and other phreatophytes

and in dry years, pre-plant irrigation of annual crops for leaching purposes and the selection of highly water-consumptive crops. (The last two regulations may be rewritten).

Another public hearing will be scheduled, and some further modification may be made before adoption. It is evident that these regulations will address many aspects of irrigation and other farm operations.

PL 92-500: BEST MANAGEMENT PRACTICES

As a result of recently signed legislation further amending Public Law 92-500, discharges of irrigated agriculture are now considered to be non-point discharges and subject to 208 Planning. In view of the great national concern, as well as state concerns, for water conservation in irrigated agriculture, it is likely that efforts will be made to establish what might be termed Best Management Practices involving the total quantities of water used to grow given crops on given soils under given climatic conditions.

GOVERNOR'S COMMISSION ON WATER RIGHTS

A special commission was created May 11, 1977 by the Governor to review California's water rights law, to evaluate issues and proposals for changes in the law, and to recommend appropriate legislation in an advisory report to the Governor. Six topics have been selected by the Commission for intensive review. These are:

1. the prior appropriation system for surface water,
2. groundwater rights,
3. the legal aspects of water conservation,
4. riparian rights,
5. transferability of water rights, and
6. instream water uses.

The third topic dealing with water conservation includes such issues as the duty to conserve water, rights to conserved water, and legal questions arising from use of reclaimed water.

Background papers have been prepared for each topic followed by public hearings. The Commission is now in the process of considering information received.

The last comprehensive review of California water rights was made by a Conservation Commission between 1911 and 1913. Changes were amended into the State Constitution in 1928. Meanwhile other western states with physical conditions and resource management problems similar to those in California have made substantial changes in their water rights laws. Thus it is expected that the California Commission will propose a number of significant changes some of which, at least, are expected to facilitate water conservation especially by agricultural users.

WATER PRICING

There has been growing public concern about prices charged for irrigation water. Two kinds of concerns are expressed. One is that farmers are not paying a price for water which properly reflects its full costs of development and conveyance to the farm, and thus, in the view of some, farmers are excessively subsidized. Delivery of inexpensive water to the large corporate farms draws particularly blunt criticism. Secondly, there is concern about the relatively low price of water because it is viewed as failing to provide adequate incentives to use it efficiently. Recognizing that supply contracts with the Bureau of Reclamation and perhaps with some other agencies do not allow price readjustment for a considerable number of years into the future, some are even advocating that water prices should be raised now by imposing a tax to achieve more efficient use. Some propose that these tax revenues be used to subsidize purchase and use of more efficient irrigation equipment and/or improve water conveyance facilities.

It is clear that future water projects, often having to use less desirable sites, will usually require more construction. This, combined with the dramatic rise in construction costs, will necessarily make future water much more expensive. Further, the new National Water Policy is expected to require irrigators to pay higher interest charges and a larger share of the total project costs. Thus, it is obvious that future water supplies will be much more costly.

Another factor contributing to higher water prices in the future will be the cost of energy. It is estimated that the California State Department of Water Resources will have to pay about ten times more per unit of power used to pump water over the Tehachapi Mountains than paid under the present contract, which expires in 1983.

Thus a combination of more difficult water projects, higher construction costs, a policy to charge the irrigator full costs, and higher power rates will combine to make water a much more expensive commodity in the future. This will certainly have major implications for the irrigation farmer in selecting his irrigation system and in managing it. It also will be an increasing factor in the choice of crops. As forecast by the study report prepared within the California State Department of Water Resources, to which I made previous reference, when the full impact of these higher water prices is known to the farmer, some of the presently low valued crops will either have to increase substantially in market value or drop out. This Report anticipates that the acreage planted to feed and forage crops in California will decrease substantially.

An indicator of things to come is the introduction in October 1977 by Representative Miller of H. R. 9592 which would require the Secretary of Interior to establish a table of water rates to be charged irrigators who contract for water from the USBR. Under this proposal, base volumes would be established for crops suited to the region considering such factors as annual rainfall, other climatic conditions, and other conditions affecting the amount of water needed to grow crops indigenous to each region. This Basic Price shall reflect the cost of delivering water including energy. Water used in excess of the base volume will be charged for at increasing rates. No water would be delivered which exceeded 2.5 times the Base.

SUMMARY

Now that copious rains have fallen this winter in California, water supplies for 1978 are expected to meet all contractual commitments and allow deliveries of some "surplus" water. However, in the longer run, California appears to face a significant deficit between presently proposed water projects and projected water requirements based on population and agricultural use to which must be added, as yet unquantified, amounts for protection of the Delta and San Francisco Bay environment, water quality for export and in-stream uses and for power plant cooling and possibly other uses.

This paper briefly summarizes present and now proposed water supplies, present and projected water needs, and the possible contributions toward balancing supply and needs arising from provisions of Senate Bill 346, increased conjunctive use of groundwater basins, use of reclaimed wastewater, and greater water conservation by urban and agricultural users.

Brief discussions are given of proposals by the State Water Resources Control Board concerning reasonable and unreasonable use of water, possibilities under PL 92-500 of specifying best management practices relating to water quantity as well as quality, studies to be made by the Governor's Commission on Water Rights, and of expected changes in water pricing and their probable impacts on water use.

Prodded by stimuli arising out of today's societal attitudes, irrigation agriculture will be called on increasingly to use irrigation water with greater efficiency and in some cases to irrigate crops from deficient supplies of water during so-called "dry" years and perhaps, in some cases, even in normal years. We may see increasing pressures to control irrigation practices through some type of regulations, greater incentives for water conservation through higher water prices, cost sharing loans and/or grants to improve irrigation systems, and possibly even restrictions (economic or regulatory) on cropping patterns in some cases.

Farmers will need to give increasing attention to the energy requirements of alternative irrigation systems which they might select and to the effects of different operational patterns on energy.

There are so many far-reaching proposals now being advanced at various levels of government that it is important for all to keep well informed as these new approaches develop and are implemented.

TABLE 1

CALIFORNIA WATER PICTURE

Total Supply

Average annual precipitation 200 MAF
65% lost through E and ET from natural evaporation and grasslands
71 MAF yearly runoff in streams

40% (28 MAF) in north coastal area
31% (22 MAF) Sacramento River system
9% (7 MAF) San Joaquin River system
20% (14 MAF) scattered over rest of state

4.4 MAF imported from Colorado River

1/4 of total average runoff (18 MAF) now protected under wild and scenic rivers

Groundwater

Total capacity 1.3 BAF
Usable capacity 143 MAF
Overdraft 1.2 to 2.2 MAF in normal year

TABLE 2

CALIFORNIA WATER SUMMARY (cont.)

WATER USE (1974)

M & I	5 MAF	(13%)
AGRICULTURE	32 MAF	(87%)
Total	37	

WATER USE PROJECTIONS

1. Based on 4 population alternatives and 4 trade alternatives
   To increase from 37 MAF
   By 1990 to 41-46 MAF
   By 2020 to 43-55

2. Additional factors increasing water demand
   Protect water quality and environment of Delta and S. F. Bay ?
   Instream uses (Fish & Wildlife) above Delta ?
   TOTAL ?

NEW YIELD REQUIRED (based on population and trade projections)

(projected)	(present use)	(USBR uncontracted)	
46	-37	-2.8	= 6.2

To correct groundwater overdraft

1.4 (San Joaquin Valley)	+ .6 (rest of state)	= 2.0
		8.2

TABLE 3

BALANCING PROJECTED WATER SUPPLIES AND NEEDS

PROJECTED DEFICIT (year 2000) about	8.2	(statewide)
1. SB 346		
North of Delta Components	1.17	
Delta Components	1.0	
South of Delta Components	.56	
	2.7 [1)]	
2. Conjunctive Use of Groundwater		
Sac. Valley (Stony Ck & Thermolito)	.5	(plans suspended)
South of Delta (Tulare & S. Coastal)	.4	
Rest of State (Mokelumne R. & others)	?	(possibly up to .5)
3. M & I Waste Water Recycling		Potentials [2)]
Present reuse .2		1.4
1982 goal to increase by .4 (Gov. Target)		
and by 2000 to increase to	1.0	2.5
4. Conservation		
M & I	1.5	(statewide)
Upstream from Delta (largely Central Valley Agric.)	.4	
Changing cropping patterns, i.e. reduced feed and forage crops	?	(statewide)
TOTAL	6.5 + ?	

1) Fulfills existing and contemplated contracts and obligations of CVP and SWP only, not statewide water deficits.

2) Potentials only for basins discharging to brackish or saline waters.

TABLE 4

1972 WATER USE EFFICIENCY AND OPPORTUNITIES FOR WATER SAVINGS BY AGRICULTURE (Bull. 198, Table 28, condensed)

Hydrologic area	Irrigated land (1000 acres)	Basin Efficiency Present %	Basin Efficiency Optimized %	Possible Water savings (1000 AF)	
Coastal					
North	249	74	80	40	
San Fran. Bay	105	70	85	40	
Central	449	83	No inc.	0	
South	431	85	No inc.	0	
					80 W/
Colorado	719	66	73	400	400
Lahontan					
North	135	64	75	60	
South	78	91	No inc.	0	
					60 W/
Central Valley					
Sacramento	1530	67	75	520 1/	
Delta-Central	828	80	Minor chg.	0	
San Joaquin	1364	73	75	110 2/	
Tulare	2166	96	Decrease to 90	-460 3/	170
		TOTALS (1000 AF)			710
		(MAF)			.71

TOTAL APPLIED WATER = 31.7 MAF   PERCENT SAVING $\frac{.71}{31.7} \times 100 = 2.2\%$

ENERGY AS AN AGRICULTURAL INPUT

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Energy Use in Agriculture

Although our agricultural production, processing and transportation system is highly mechanized and energy dependent it uses a relatively small percentage of the energy used by our economy as a whole. The 1974 report, "Energy Requirements for Agriculture in California"[1], based on 1972 statistics, gives the energy required to produce, transport and process our food and fiber. The processing energy in this report, included only that required to place the produce in storage in a stable form. The report indicates that California agriculture used slightly more than five percent of the total energy used by the State. Table 1 shows agriculture's use of the major energy source in comparison with the State as a whole. Agriculture's percentage of the total would be somewhat greater if all the energy for processing and for transporting our agricultural commodities to the retail level were included.

The above report also pointed out some interesting facts about energy use within the agricultural sector. For example, natural gas represented 53.1 percent of the total energy reported for agriculture, most of which is used for processing. Fertilizers represent a major energy input for agriculture; their production, distribution, and application represented 14.9 percent of the total. Approximately 90 percent of the energy represented by fertilizers was natural gas used in the production process. Irrigation pumping used 13.2 percent of the total energy and nearly 70 percent of the electricity in agriculture.

A more detailed study on irrigation energy requirements was recently completed with a report titled "Pumping Energy Requirements for Irrigation in California".[2] Fig. 1 shows a comparison between irrigation energy use and other key, on-farm energy requirements. It is of interest to note that the irrigation energy requirement is greater than that for the combined categories of crop establishment and cultural practices. Fig. 1 also shows the four components of irrigation energy use that comprise the total. The on-farm well portion is slightly more than 50 percent. A study is in progress to up-date and expand the data on natural gas use by California agriculture. This study is a joint project between the Department of Agricultural Engineering at U.C. Davis and the California Department of Food and Agriculture.

Energy Supply and Price

The availability and cost of fossil fuels and electricity are of critical conern to all sectors of the economy.

The 1976-77 drought in California and the West reduced hydroelectric power generation which made it difficult for power companies to meet the demand. It also increased the price because more expensive electricity was generated in thermal power plants to make up for the loss of hydroelectric power. For example, the P. G. & E. system normally produces 49 percent of its electric power from hydro. In 1977 the hydro portion was reduced to less than 20 percent. The drought had a double effect on electric power supply in that irrigation pumping increased and farmers were forced to pump more water and from greater depths.

The situation is particularly critical for natural gas because of reduced supplies from domestic and foreign sources. Some agricultural users have converted to fuel oil and others are expected to convert as the supply situation tightens. The Public Utilities Commission has established a priority system for curtailment of natural gas to customers as the supply decreases. There are five curtailment priority categories with Priority 1 being the highest and Priority 5 the lowest. The system gives a consumer a priority rating based on size, feasibility for conversion to an alternate energy source, and the process by which the gas is being consumed. Agricultural users of natural gas fall into various categories depending on the factors above.

Recent projections by the California Energy Commission indicate that by early 1978 Priority 5 users will be curtailed in northern California and Priorities 4 and 5 in southern California. LNG (liquified natural gas) from Alaska and/or Indonesia will provide the only major increase in supply in the next several years if provisions are made for delivering it to the lower 48 states.

The California Energy Commission has also projected prices for natural gas and electricity for the period from 1975 to 1990. Natural gas price is projected to increase by 100 percent from 1975 to 1980 followed by a 100 percent increase from 1980 to 1990. The price of electricity is projected to increase by 50 to 90 percent from 1975 to 1980 with a 30 percent increase for each five years thereafter.

Alleviating the Energy Squeeze

Higher costs and reduced availability of energy have resulted in more efficient use of this important production input. Processing plants and drying operations have been improving boiler and burner efficiencies. Many processors have thoroughly checked their plants for places where energy can be saved. These checks have eliminated leaks in hot air, steam and hot water lines. Many plants have also installed insulation on air ducts, hot water pipes, and other equipment to reduce energy losses. Farmers have been improving irrigation efficiencies by replacing or overhauling pumps and by minimizing the amount of water used.

All segments of agriculture are monitoring their energy inputs and initiating conservation practices. Conservation is an important part of a total effort to save energy and can also be a method of reducing costs.

Alternate Energy Sources

The increased cost of energy has made alternate energy sources more attractive. There are many sources of energy being studied, however, I will limit my remarks to the two sources that I believe have some potential for on-site recovery and use in agriculture. These two sources are biomass conversion and solar.

There are three primary methods being evaluated for converting plant materials to energy; these are gasification, incineration, and pyrolysis. Of these three, gasification and incineration appear to have the most potential.

Gasifiers have been in existence for many years but the process is being tested as a means of converting crop residues to a gas which has a heat content of about 150 BTU per cu. ft. The gas can be used as a source of heat or it can be used to fuel an internal combustion engine. Test results to date indicate that this process will not create serious air pollution problems and provides an overall heat recovery efficiency of about 75 percent.

Crop residue incinerators are also being evaluated as a source of heated air or steam for agricultural processing and drying operations. It is difficult to control exhaust stack emissions so they will meet California air pollution standards and the overall heat recovery efficiency is less than for the gasification process.

A number of crop residues are being tested for gasification and incineration including, cotton gin trash, corn cobs, rice hulls, wood waste, and grain straw. Collection, handling and storing is a major problem for residues normally left in the field. Most materials must also be densified for handling and/or conversion purposes. Certain types of material have created slagging problems in the ash.

Solar energy is another potential source for such operations as drying and dehydration, low temperature hot water heating, and space heating of buildings and greenhouses. The major problem is that solar energy is not cost competitive because of the equipment investment required.

Conclusions

Agriculture uses a relatively small percentage of the total energy used by our economy, but this energy input is vital to the production of food and fiber. A 1974 study reported that California agriculture uses approximately five percent of the total energy consumed by the State's economy.

Conservation and new sources of energy are the two approaches that must be pursued. Biomass conversion offers real potential for use in agriculture in the near future. Solar energy has long range potential but is not cost competitive for most applications at the present time.

Natural gas supplies are being depleted, forcing curtailment of use in agriculture as well as other sectors. Many processing plants have converted from natural gas to fuel oil which is much less convenient and generally more expensive. Nitrogen fertilizer production is highly dependent upon a continued supply of natural gas both as a feedstock and a heat source.

Increasing energy prices are creating serious economic problems in agriculture. Electrical energy costs for irrigation pumping are fifty dollars per acre foot and higher in some areas of the State. The alfalfa dehydration industry has essentially disappeared from California because of high energy costs in the dehydration process.

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2. "Pumping Energy Requirements for Irrigation in California". G. D. Knutson, R. G. Curley, E. B. Roberts, R. M. Hagan, V. Cervinka. University of California Special Publication 3215. July 1977

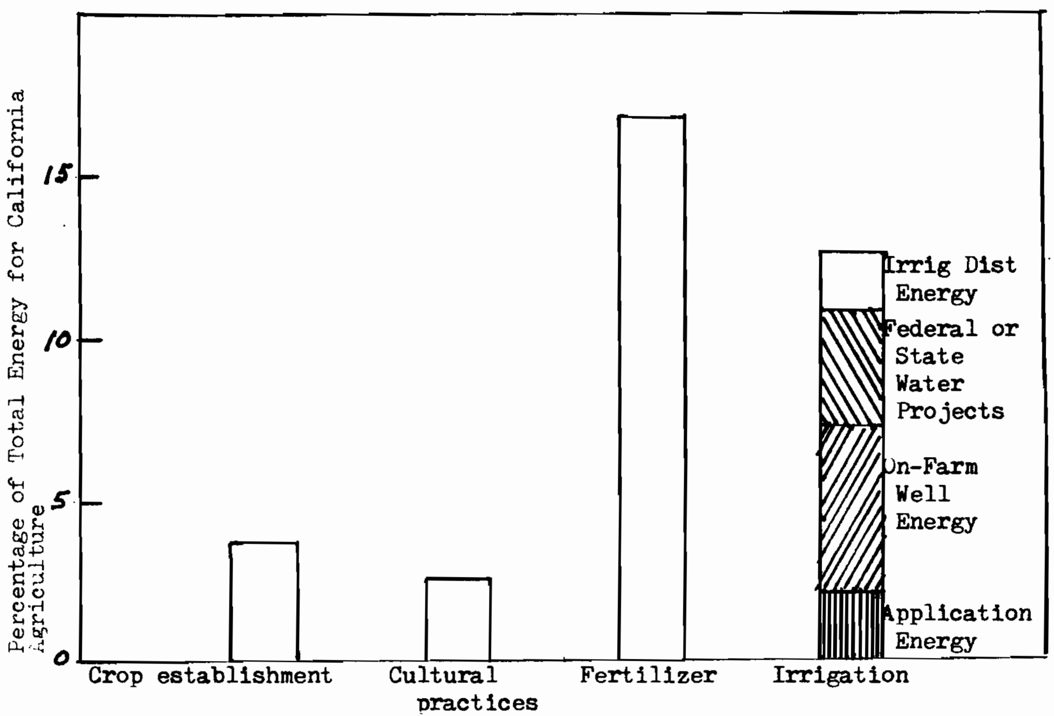

Fig. 1. Comparison of irrigation energy with other key energy requirements for California agriculture. Energy requirements for crop establishment, cultural practices, and fertilizer are taken from the 1974 report "Energy Requirements for Agriculture in California" by the California Department of Food and Agriculture and the Department of Agricultural Engineering, UC Davis.

Table 1

PROPORTION OF ENERGY CONSUMED
BY AGRICULTURAL INDUSTRY IN CALIFORNIA

ENERGY SOURCE AND UNITS		STATE OF CALIFORNIA 1/	CALIFORNIA'S AGRICULTURAL INDUSTRY	
		1,000,000 UNITS		%
NATURAL GAS	THERMS	23,588.537	1,214.218	5.15
ELECTRICITY	KWH	135,241.711	10,575.340	7.82
DIESEL FUEL	GAL	2,659.356	292.584	11.00
GASOLINE	GAL	10,037.916	195.198	11.94
LP GAS	GAL	458.933	52.629	11.47
AVIATION GASOLINE	GAL	42.738	8.994	21.04

1,000,000 Barrels of Crude Oil Equivalent	
Total direct energy use	39.432 Bbl.
Heat energy rejected in electricity generation 2/	11.815 Bbl.
Total energy associated with agriculture	51.247 Bbl.
Total energy use in California (1972) 1,3/	1,010.247 Bbl.
Percent of California energy used in agriculture	5.072

1/ Sources of information:

"Electric Power Statistics", Federal Power Commission, January 1972 through December 1972 issues.

U. S. Dept. of the Interior, Bureau of Mines, Mineral Industry Surveys, Liquified Petroleum Gas/Annual, October 25, 1973.

Personal Communications, California Department of Conservation, Division of Oil and Gas, January 10 and 24, 1974.

U. S. Department of Interior, Bureau of Mines, Mineral Industry Surveys, Natural Gas/Annual, November 8, 1973.

2/ The oil equivalent (17) of heat energy rejected (assumed efficiency = 34.5%) upon generation of electrical energy used in agriculture.

3/ Includes energy from coal, jet fuel and residual fuel oil, as well as the input oil equivalent (at 34.5% assumed efficiency) of electrical energy generated by hydroelectric, nuclear and geothermal installations.

ARE OUR RESOURCES MANAGING US?

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The basic wealth and progress of any nation has always depended, in large part, on its available resources. Certainly, our fortunate circumstances stem from blessings we inherited--our land, air, water, mineral and human resources. And certainly, the ultimate limits on California agriculture's productivity will be determined by the quality, cost, availability and utilization of these resources.

It is not only the limits of our food and fiber supply that will be set by these factors. Our future economy, security, health and well-being--the quality of life--will depend largely on the fate of the resources we have used and abused so freely.

A slightly exaggerated description of the quality of life after all of our resources and raw materials have been used up was given some years ago by former University of California President Clark Kerr. He was talking about the population explosion--"Perhaps the greatest phenomenon in the history of mankind"--and the effect the added billions of people would have on the world. He referred to the research on algae then underway at Berkeley, involving large tanks of sewage in which algae were being grown. The algae purified the sewage so that the water could be used over again and the algae could be used as food. His tongue-in-cheek vision of the world's final chapter went something like this.

The barren planet is almost completely covered by a series of algae tanks with small colonies of people living on grids on top of each of the tanks, just sitting there broiling in the sun, eating algae, and life is a self-perpetuating cycle of sewage to man to sewage. There isn't any point in travel because there are just algae tanks wherever you go. There isn't any point in studying history, because as far back as you can go, there is nothing but algae tanks. No point in looking forward to the future because, as far as anybody can see, it is just more algae tanks. That is certainly a dismal and dreaded projection of the future.

Well, today we are living in the "good old days," and we have a more varied menu, better scenery and more reason to travel, better shelter, more reason to look to our past, still have good reason to look to the future, still can anticipate a quality of life beyond the limitations of the algae tank. But if we want to keep it that way we had better program a wiser and more prudent course of resource management and use, or our resource situation will dictate our course for us. If we want our children and their children to enjoy those more varied menus, and the good things the food and fiber industry does for our economy, it behooves all of us involved in the agricultural enterprise to do more than we have to conserve and maintain the critical components required for that enterprise in the future.

Whether we long for the good old days or look forward to growth and progress, the fact is that the world has changed and change will inevitably impose new conditions on agriculture in the future. But change can be positive--we are beginning to learn--only if it is accomplished within the constraints imposed by the available resources and existing ecological characteristics of the area in question.

The present energy situation illustrates how a change in one resource could have different results, depending on the social and technological conditions of the area involved. In California agriculture, for example, large amounts of energy are required--not only for the production of pesticides and fertilizers and the manufacture and operation of machinery and equipment for the planting, harvesting, processing and transportation, but also for the pumping of underground water and movement of surface water for irrigation. In 1977, which might be described as a year of lowered ground water levels, the energy requirements for agricultural pumping in the Central Valley were calculated to be 5.91 billion K.W.H.

Because technology has made modern, California-style agriculture essentially a process of converting calories--of converting energy into food--it is obvious that the cost of the farmer's products will rise when the cost of energy rises, and that the production of those products will be seriously disrupted if the energy supply is significantly reduced. In less developed countries less committed to Western ideas of progress, innovation, and technology, the much smaller agricultural energy requirements are met largely by human and animal muscle power, and the changing energy situation will not have the same direct effect. Theoretically, plentiful supplies of low-cost energy would enable these countries to increase agricultural productivity through substantial increases in the use of mechanical horse power, pesticides, fertilizers and irrigation. But because this approach requires technical know-how and a substantial base of technological resources, many of the underdeveloped countries may have to depend on improvement in their traditional farming methods, rather than innovation to boost their productivity.

On the other hand, the changing situation for energy and other resources may well force our technology-based agriculture to depart from its traditional patterns. Improving or maintaining our production capacity may demand not only a greater degree of resource management but a much greater degree of industrialization and even a restructuring and relocation of some parts of our food production system.

Management of resources is essentially what agriculture has been doing for the past 100 years. The management systems developed over the years grew out of an effort to exploit our seemingly limitless resources to increase the farmer's productivity and reduce unit costs. But now, for a lot of reasons, and within a very short period of time, the rules of the game have changed.

Despite droughts, power blackouts, and oil embargoes, we are not about to run out of water and energy next week, but the demands on these limited resources are increasing at an alarming rate, and so are their costs. We can no longer afford to ignore the fact that the changing status of these resources poses a long-term threat to the productive capacity and competitive position of California agriculture and its important contribution to the economy.

Because our food and fiber system largely depends on fuels, fertilizers and chemicals which are petroleum-based, one can get a very insecure feeling by contemplating the depletion-history of crude oil in this country, the rapidly rising rate of consumption of petroleum products, and the growing dependence on foreign sources for those products. The fact that we now depend on imports for almost half of our petroleum supplies--up from 3 million barrels per day in 1970, to 9 million in 1977, suggests that we are not entirely in control of our own destiny.

For agriculture, it is a sobering thought that the natural gas and petroleum energy supplies needed for agricultural production, processing, transporting and marketing are declining and increasingly expensive. It is equally sobering that there are no alternative energy sources on the horizon that could even approach present usage levels. It is sobering to contemplate the technologial development and disruption of our present food and fiber system implicit in a change-over to an energy supply other than petroleum--<u>if</u> there was one.

It is reasonable to ask the questions: Can we in the future afford crops that yield less energy than is required to produce them, or can we afford to use expensive energy from foreign sources to produce energy-intensive commodities and use more energy to get them to foreign markets? If five California commodities use 97 million gallons, or approximately half of the diesel oil used for all of the state's agriculture, will societal pressures at some point dictate that some of these crops, such as sugar beets, be cut back or replaced by commodities of greater value to society?

Natural gas represents 50 percent of the total energy consumed in California agriculture. In 1972 the processing of only 12 commodities required half of the natural gas used, or the equivalent of 10 million barrels of crude oil, which was twice the amount required for the production of fertilizers. When the natural gas crunch gets a little more crunchy, will processing for sales appeal and convenience purposes stand against pressure from those who prefer to have their homes heated or the growing numbers who prefer their food to be "natural" and unprocessed?

Agricultural production must be recognized as an efficient user of energy. Its 3 percent share of the energy consumed in the United States is less than that needed to fuel the nation's jet aircraft; it feeds more than 200 million Americans, and provides enough exports to pay for two-thirds of the country's total imported energy. Nevertheless, economic pressures, the impact of ever-increasing energy costs, will bring every energy use under scrutiny and force agriculture to seek ways to manage energy resources even more efficiently. And questions are being raised now, in the media and in public forums, about agriculture's so-called "wasteful" use of energy.

Higher energy costs will be a more serious problem in areas and for agricultural products for which energy costs are already high. California agriculture will face serious difficulties in coping with rising costs and a restricted supply for a number of reasons. Our absolute dependence on irrigation makes for much higher energy requirements compared with rain-watered farmland in the Midwest and Eastern states. In 1972, water pumps for irrigation required 13 percent of the energy used by agriculture in California. Since then, the increased acreage under irrigation and the drop in ground water levels during the past two years have undoubtedly increased pumping requirements.

Many California crops will be at a disadvantage in the coming energy squeeze. An energy-intensive crop such as cotton will fare poorly as compared with wheat and oats. Vegetables and fruits have much higher energy requirements than field crops. Some commodities such as sugar beets and canning tomatoes are near the top of the list as users of both oil for production and natural gas for processing. Because of its large number of specialty crops a large share of the state's agricultural products are exported. Transport to distant markets, particularly for perishable commodities, is another high energy factor.

In this scenario, the California farmer will have a number of unhappy choices in his accommodation to a less happy energy situation. He may change his operation to make it more efficient within his environmental framework. He may cut down his consumption of energy through such practices as reduced tillage. He may switch to crops with lower energy requirements. He may employ alternate energy with power derived from solar, wind or biomass sources. He may go into a more promising line of work, such as algae tank construction.

And indeed the question might well be, not <u>how</u> California agriculture can survive through more efficient use of resources, but <u>will</u> it survive, unless some other societal concessions are made to sustain it. Long before the advent of the post-petroleum age it will become apparent that superior productivity alone is not enough. Without question there will be <u>some</u> kind of agriculture <u>somewhere</u>, but competitive energy costs may determine location and whether some crops with high energy requirements and low nutritional value will be grown at all. What kind of agriculture would California have if energy costs were quadrupled in 20 or 25 years? If that strikes you as an unreal question, let us contemplate the political uncertainties associated with some sources of the imported oil on which we depend. Let me cite a figure from a recent "Newsweek" article on energy, a figure that gives some measure of this country's enormous appetite for energy and of the relative size of our oil reserves. "Despite all the ballyhoo surrounding the opening of the Alaska oil pipeline this summer, total reserves of the Prudhoe Bay field represent only $17\frac{1}{2}$ months' worth of oil at current rates of consumption."

This line of thought can stimulate a number of interesting questions. Will a reduced energy supply provide a winning argument for the political campaign now underway to halt the University's farm mechanization research and agriculture's efforts to mechanize more production processes? Will it even eliminate machines currently in use? Will the man with the hoe, and the small, labor-intensive farm enjoy a renaissance? If the energy used in the interdependent activities that produce, transport and process the state's crops and livestock is sharply reduced, will countries like Mexico and Taiwan take over our markets? If the energy situation forces processors to alter significantly the form in which products reach the market, what major changes will this make in our crop and livestock production? How soon will our eating habits change in adjusting to these developments? How soon will it become apparent that our resources are managing us?

Many of the same considerations and conflicts of interest, and the same kinds of questions, will surface as our water resources decrease and the demands on them increase. California agriculture has long maintained a reputation for its diversity and high ranking in the production of specialty crops. But as the available water supply is curtailed or reduced and the energy to move it is restricted and expensive, California farmers may be forced to concentrate on commodities with low water requirements and the present 200-plus commodities might well be whittled down significantly. Alfalfa and irrigated pastures could go the way of fruits, nut and vegetables, and our hot, arid valleys might revert to "amber waves of grain."

Agriculture's political clout is not flourishing, and in the growing competition and conflicts among water users, the expanding industrial and urban interests will no doubt continue to gain ground. What kind of agriculture would California have if in 15 or 20 years our urban-dominated policymakers decided that agriculture's share of the water supply should be reduced from 85 percent to 50 percent? Or 40? I'm told that we now use water at the extravagant rate of 326,000 gallons per year for every man, woman and child in California. And I'm told that California will have 1.8 million more of those moisture-seeking men, women and children by 1985.

As the pressures of population, industrial growth and environmental preservation increase we will be compelled to look at social and economic price tags for water usage and make hard decisions regarding the same kinds of tradeoffs we will face with our energy resources. We may not only have to choose between agricultural commodities but between agricultural industries and other sectors of the economy. Do we grow tomatoes or make steel? Do we build nuclear power facilities that require water for cooling at the rate of 800,000 gallons per minute? Can we still preserve water quality necessary for the vital life-support systems of our bays, estuaries and wetlands?

Pollution of our water resources affects everyone--but then so does the production of energy and the production of food. When the chips are really down we could make decisions regarding swimming pools, car wash establishments, green lawns, recreation water sports and perhaps even the feeding of people beyond our borders. But the use of our resources is clearly based on economics, and if the choice is between water for energy or food production, or land needed by the farmer or the developer, presently agriculture invariably comes out second best.

At some point we will achieve the wisdom or be forced to recognize that our natural resources--and particularly land and water--are inseparably related to the condition and well-being of the society that uses them. We will have to face up to the questions of who owns the water, and what our responsibilities are for the land resource that must provide the basic needs of the generations to come. If we do not establish priorities and develop alternatives, the generations to follow may not have those options because the resource base may have been irreversibly damaged or depleted.

Given the population prospects for the state, and the world, increased agricultural production must still rank high among our priorities, but we must find ways to achieve it with minimal damage to the environment and with the lowest possible inputs of those "irreversible" resources of land, water and energy. California's fortunate position in the food and fiber department has come about through the applications of past research as well as from a generous endowment of resources. We are harvesting the fruits of years of substantial effort and progress in agricultural science and technology.

The challenge of the future is of a new magnitude because our food and fiber prospects are intertwined with world events and resource developments of the kind referred to in this discussion. If future needs are to be met it will, in large measure, depend on another kind of resource--the kind represented in this room. Future yields will depend on research underlying the conservation, development and use of our resources; how they can be replenished, reused and substituted for; and on research to provide a better basis for resource planning and policy formulation.

Basic technological data exist that could be used to make more effective use of resources for increasing agricultural productivity. Analysis and synthesis of information already developed about each resource and its management would be required. Such an effort would be valuable in pinpointing critical gaps in our knowledge and as a basis for implementing management practices and planning future research.

Because agricultural yields are dependent on only partially understood factors of climate and biology, on unpredictable and evolutionary changes of a socioeconomic nature, and on unforeseen technological developments, we can anticipate and must be prepared for setbacks and problems as well as new opportunities. Unexpected droughts, new pollutants, changing ideas about diet and nutrition, ecological imbalances and new governmental constraints may be on our future agenda, and all would require corrective and adaptive responses derived from research. Only when we have achieved a better understanding of the basic process involved and have developed a range of possible alternatives and realisitic options to our current practices can we cope with the foreseen and unforeseen changes that will surely come.

For the long term, our ability to cope--our ability to meet our food needs--will be heavily dependent on research findings not yet produced. Agricultural production can match the expanding demands of the coming decades only if new technologies are developed. The only source for these new technologies is new research. It is the innovations now evolving in our research laboratories that will have a major impact on our food production performance in the year 2000 and beyond. Research plans and decisions made now, or the lack of them, will therefore affect our prospects and our options in the future and how well our food and fiber system will be able to adapt to changes in the cost and availability of essential resources.

We are approaching a critical period in the course of our resource practices. In a time of relative plenty it is easy to be complacent, and many current practices have justified themselves by past successes. But a drought and an oil embargo have given us a taste of the disruption that a changing resource situation may generate. Those successes of the past and present may bring about the disasters of tomorrow. They may increase the difficulty any society has in changing established, traditional practices.

As the rate of change accelerates, flexibility and innovation rather than tradition will enable us to cope with stresses in our complex systems of resource use and management. As the lead time diminishes and the tempo and urgency increases, the agricultural sciences will have a central role in helping provide access to adequate supplies of food while preserving the variety and beauty of our planet.

We may have time to manage our resources before they manage us, but the time to develop our research strategies to combat our future resource problems is now.

ORGANIC MATERIALS AS NITROGEN FERTILIZERS

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The plant availability of N in organic materials added to soils is dependent on the nature of the materials and on soil, climate and management factors. But, because the nature of the materials has such large effects, this paper presents the results of calculations based on estimated annual rates of mineralization and presents data from field and greenhouse estimates of N availability in several organic materials.

Numerical indexes to mineralization, referred to as decay series, were estimated and used in calculating the trends in N availability over a 20-year period in relation to the numerical coefficients in the decay series and to broad management alternatives. Calculations show that at a constant annual rate of application of organic N the annual rate of mineralization gradually increases to ratios of annual mineralization to annual inputs of 0.72 to 0.96 after 20 years, depending largely on the first numerical index in the decay series. For the decay series 0.90, 0.10, 0.05 - - -, in which the first number refers to the fractional mineralization of the N added in any given application, the second refers to the fractional mineralization of the residual N from this application and the third number refers to the fractional mineralization of the residual N in the third year and in each succeeding year, the ratio of annual mineralization to annual input reaches 0.96 in 20 years. For the decay series 0.20, 0.10, 0.05 - - - this ratio reaches 0.72 in 20 years.

For a desired constant amount of N mineralized per year the ratio of N inputs per year to annual amounts mineralized reaches 1.04 to 1.13 in 20 years and is inversely related to the first numerical index in the decay series. From a management point of view, adjustment of the annual input to provide for a desired annual output for a given cropping sequence is possible if the decay series for the particular materials being used are known.

Calculations show that large applications of organic materials, followed by years with no applications, create the potential for large NO_3 leaching and/or denitrification losses followed by years in which the supply of available N by mineralization of the applied materials are not sufficient to meet the needs of plants.

The mineralization of N from a fresh liquid feedlot manure having 4.5% N, during a 4-year field trial was estimated by a decay series of 0.75, 0.15, 0.10, 0.05 - - -. This material was added to the plots and incorporated into the soil within 48 hours after production so that there was little chance for loss of N as NH_3 and thus most of the urea N would have been preserved. In the same field trial the N mineralized from a dairy corral manure having 1.6% N was estimated by a decay series of 0.45, 0.10, 0.05 - - -. In this case the urea N had probably all volatilized as NH_3 during the time the manure was accumulating on the corral floor.

In a greenhouse pot test with a manure having 1.5% N and a sewage sludge having 4.2% N the available N estimated from the amount required to equal $(NH_4)_2SO_4$-N in terms of barley forage production. In a 2.5-month period following application the manure gave an average of 0.65 kg of available N per ton whereas the sludge gave 7.05 kg of available N per ton. This represents 4.2% of the total N from the manure and 17.0% of the total N in the sludge. In a 10-month period only 17.2% of the N in the manure had mineralized and 40.9% of the sludge N had mineralized.

SEWAGE SLUDGE AS A SOURCE OF
PLANT ESSENTIAL NUTRIENTS

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Sewage sludge is the residue resulting from the treatment of minicipal wastewaters. It has and continues to be used on lands as a low grade fertilizer and as a soil conditioner. Sewage sludge is also used as a filler material in the processing of some commercial fertilizers. A number of companies in the U.S.A. and abroad market sewage sludges or sewage sludges fortified with additional quantities of plant essential nutrients, usually nitrogen and phosphorus. Examples of commercial sludge derived products used in agriculture and in landscaping are "Nitrohumus" which is composed sewage sludge from the Los Angeles County Municipal Sanitation District and "Milorganite" which is a processed sewage sludge from the Milwaukee, Wisconsin sewage treatment plant facility.

Sewage sludges contain varying quantities of all plant essential nutrients. The concentrations of total nitrogen usually vary from 1 to 10 percent, phosphorus from 0.5 to 3 percent and potassium from 0.05 to 1.0 percent (Table 1). For the N, P, and K to be effeciently utilized by plants, they must not only be present in sufficient quantities of plant available forms, but also in proper proportion. Unlike manufactured fertilizers whose proportion of nutrients can be formulated to suit soil or plant needs, plant nutrients in sludges are uncontrolled. For this reason, applying sludge to satisfy the requirement of one nutrient may make other nutrients excessive or deficient.

Nitrogen is the element which usually occurs in sewage sludges at the highest concentration. It is also the most common nutrient element applied to soil to correct deficiencies. Therefore, it is logical to consider use of sludge in agriculture as a supplement source of nitrogen. The nitrogen in sludge is present in the inorganic and organic form. In liquid sludges, approximately 50 percent of the total nitrogen is present in the inorganic form. When sludges are dewatered, the soluble inorganic nitrogen to a large extent is removed with the water. Consequently, the nitrogen concentration of sludges (expressed on a dry weight basis) diminishes in proportion to the extent of dewatering.

Organic forms of nitrogen in soils must be converted to inorganic forms to render the nitrogen plant available. The rate of this microbial-related conversion depends upon a variety of environmental factors such as soil moisture and organic matter content, aeration, pH, temperature, and nitrogen in the inorganic state. Although the rate at which organic nitrogen is converted to inorganic nitrogen is not precisely known and is undoubtedly influenced by soil factors, the available evidence indicates that approximately 20 percent of the applied organic nitrogen is converted to plant available forms within the first twelve months of its application. Each succeeding year, part of the remaining organic nitrogen is mineralized, but at a magnitude considerably less than that of the preceeding year.

In most liquid sludges, the inorganic nitrogen is present in the ammonical form. Where sludges are applied to the surface of soils and not immediately incorporated, a large percentage of the nitrogen is lost as gaseous ammonia.

To estimate the quantity of sewage sludge required to supply soils with adequate plant available nitrogen, for example, 180 kg/hectare, we will assume that 50 percent of the applied inorganic nitrogen is lost by volatilization, and that 20 percent of the organic nitrogen is converted to inorganic nitrogen during the cropping season. If a sludge contains 3 percent total nitrogen of which 50 percent is inorganic, one metric ton of sludge, under the above conditions, would supply 10.5 kg of plant available nitrogen during the first year. To satisfy 180 kg/hectare plant available nitrogen requirement, 17 dry metric tons equivalent of liquid sludge is required.

To evaluate the amount of other plant nutrients and other selected elements which would be applied in agricultural operations we will assume that sludge is used as a source of plant available nitrogen and that to supply available nitrogen for plants 20 metric tons per hectare are required. Table 1 shows typical concentrations of certain plant essential elements in sludge, the quantities of each element which would be supplied if its concentration in sludge were at the median level and the sludge was applied at a rate of 20 metric tons/hectare and normal fertilizer application rates.

The data (Table 1) show that if sewage sludges are applied to soils in amounts sufficient to satisfy the nitrogen requirements of crops, the accompanying amounts of other plant essential nutrients, P, S, Mg, Ca, and Zn exceed normal remedial amounts required to correct deficiencies. For K, B, Mn, and Mo the 20 metric tons rate is not sufficient to supply these nutrients in amounts considered necessary to correct deficiencies. However, continued sludge applications over a period of years should build up a large enough pool of these elements to satisfy crop requirements.

Some micronutrient elements such as B, Zn, Ca, Mo, and non-essential elements such as Cd, Ni, Pb, Cr, if present in excessive quantities in soils, may be detrimental to plant growth or may concentrate in plant tissue in abnormally high quantities that become hazardous to consumers. Sludge also contain nitrate nitrogen, soluble salts and boron which may leach and cause groundwater contamination. Therefore, when sludge is intended for use as a plant nutrient supplement, attention should not only be focused on how to satisfy all nutrient requirements, but also on protection of surface and groundwater supplies and on preventing hazardous accumulations of toxic elements in soils and crops.

Table 1. Typical concentrations of plant essential nutrients in sewage sludge, amounts applied to soil in the form of sludge when application rates are based upon nitrogen crop requirements and normal fertilizer application rates.

Element	Typical Conc'n in Sludge		Amount Applied to Soil	
	Range	Median	From Sludge of Median Conc'n*	Normal Application as Fertilizer
	-----------%------------		--------------kgm/ha------------------	
N	1-10	3.0	210**	180
P	0.5-3.0	1.5	300	50
S	0.5-1.5	1.0	200	10-40
K	0.05-1.0	0.3	60	100
Ca	1.0-10	4.0	800	-
Mg	0.2-1.0	0.4	80	25
Fe	1.0-6.0	1.0	200	-
	----------ug/g----------			
B	5-150	40	0.8	1-2
Cu	10-5000	750	15	2-10
Mn	100-800	300	6	10-20
Mo	1-40	5	0.1	0.5-2.0
Zn	1000-6000	1800	36	2-10

* Application rate of 20 m tons/hectare
**Plant available nitrogen - see text for details.

AGRICULTURAL UTILIZATION OF SEWAGE SLUDGE: A FIELD DEMONSTRATION

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Land application as a means of disposing sewage sludges has long been practiced by some communities in the U.S. For cases in the past, land disposal practices usually were small in scale and operated at somewhat an uncontrolled manner. There was little information offered in the published literature to establish designing criteria and operating procedures. The renewed interests in recent years of recycling wastewater sludges of urban areas on agricultural land, however, has resulted in the demand of more systematically planned and conducted experiments to generate reliable data bases in assessing engineering feasability and potential environmental impacts of large scale long term land disposal. The potential beneficial and detrimental effects of applying sewage sludge of the Los Angeles County and Orange County metropolitan area onto the agricultural land of the Southern California inland area were examined through a field scale experiment. The specific objectives were:

1. To determine the effect of soil properties on the capacity and limitation of cropland in receiving sewage sludges and the change in soil physical and chemical properties due to sludge application.

2. To determine crop response (yield, nutrient utilization and uptake of potentially hazardous trace metal elements) at various levels of sewage application on cropland.

3. To determine potential routes and mechanisms whereby groundwater and soil may be contaminated by application of sewage sludge on cropland.

For various logistic conveniences in field arrangements, the experiment was divided into three groups. Experiment A was an experiment (on 40' x 60' field plots) of winter barley followed by summer sorghum double cropping with 0, 10, 20, and 40 dry tons of composted sludge per acre per year in split application before the planting of each crop. The experiment was started in winter, 1975 on two types of soils (Greenfield sandy loam and Domino loam). At this reporting, two crops of barley and one crop of sorghum have been completed. The second crop of sorghum is well underway. Experiment B consisted of essentially the same experiment as experiment A using two liquid sludges (from the Joint Water Pollution Control Plant of the Los Angeles County Sanitation District and Hyperion Wastewater Treatment Plant of the City of Los Angeles) at application rates equivalent approximately to 0, 10, 20, and 40 dry tons of sludge solids per acre per year on smaller experimental plots (30' x 30'). This experiment was not started until summer, 1976. Experiment C consisted of growing two leaf vegetables (lettuce and Swiss chard) and two root vegetables (radish, turnip in winter and carrot in summer) on a 40' x 50' area with composted sludges applied at 0, 10, 20, 40, and 80 dry tons per acre per year. Two crops of vegetables were planted each year. No attempt was made to determine yield response.

The applied sludges, the plant tissue and the soils were sampled routinely for chemical analysis. The experiment will be continued until June, 1978. Results from past two years of experiments can be summarized as follows:

1. When the soil was not difficient in plant nutrients, the application of sewage sludge in any form or at any amount did not appear beneficial to crop yield as indicated by the yield data of earlier croppings. When plant available nitrogen in soils was depleted, sludge application increased crop yield. Once enough sludges were added to result in 2.5-3.0% N in leaf tissue, no further increase of yield was observed in barley and sorghum crops.

2. The amount of nitrogen applied that would become available for plant utilization and subject to leaching was determined by the rate of nitrogen mineralization in soils. Based on a mass balance of nitrogen, the annual rates of N mineralization were determined.

At the sludge application rates of the experiment, approximately 45% of the applied nitrogen in composted sludge were mineralized the first year. Assuming 35% volatilization loss of liquid sludge nitrogen during drying, 75% of the non-volatilized liquid sludge nitrogen was mineralized. The rate of denitrification and the extent of nitrate leaching will not be determined until the soil profiles are sampled in October, 1977. Assuming no denitrification in soils, approximately 30 dry tons composted sludges, 6 dry tons of JWPCP liquid sludges and 3 tons hyperion liquid sludges would be sufficient to satisfy the nitrogen demand of annual barley and sorghum double cropping. The calculated sludge application rates will be adjusted for N loss in soil due to denitrification and release of applied N in succeeding years (nitrogen decay series) as additional data becomes available.

3. Under field conditions, trace metal elements (Cd, Cr, Cu, Ni, Pb and Zn) did not appear very mobile in the soil profile. The increase of trace metal elements in sludge applied soils was detected only in the 0-12 inches of the profile. Calculations indicated approximately 80% of the trace metal elements in the applied sludges were accumulated at the surface 6 inches of the soil.

4. The increase of trace metal elements in soil also affected the uptake of metal elements by plants. Results from field crop experiments (barley and sorghum) indicated a variety of factors would effect the uptake of trace metal elements by plants.

   (1) Metal species effect:

   For the six metal elements determined, zinc and cadmium showed the most apparent increase in the plant tissue. There was a general trend of increase of metal concentration in plant tissue with increasing metal concentration in soils. However, the magnitude of concentrations increase in plant tissue was significantly less than that in the soil. Slightly elevated concentration of Cu and Pb in plant tissue independent of large increases in soils were also found. No increase of Ni and Cr concentrations in plant tissue were detected.

   (2) Soil type effect:

   At the same amount of sludge application, plants grown in the heavier textured, higher organic matter content Domino loam had a significantly lower amount of trace elements uptake.

   (3) Sludge type effect:

   For the same trace metal concentrations in soils, liquid sludge treated soils resulted in higher metal concentration in the plant tissue.

No metal element concentrations in plant tissue was found high enough to cause any crop damages or to show any toxicity symptom.

5. The increase of trace metal elements in vegetables were found considerably higher than that of the field crops. Under the same sludge treatment, the higher increase always occurred at the leaf portion of the plant. The metal species effect was also noted in all vegetables experimented. Trace elements concentrations of lettuce planted in spring, 1976 are summarized to demonstrate the described effect.

Sludge treatment (tons/AC/Year)	Cd	Cr	Cu	Ni	Pb	Zn
			(ug/gm in plant tissue)			
0	0.71	<5.0	6.4	<5.5	5.6	48.0
10	0.92	<5.0	6.4	<5.5	5.7	48.0
20	1.64	<5.0	8.7	<5.5	-	80.0
40	2.40	<5.0	8.2	<5.5	2.2	103.0
80	2.79	<5.0	8.2	<5.5	4.0	103.0

6. After approximately 2 years of experimentation, it appeared that the total nitrogen content and the availability of sludge nitrogen would limit the amount of sludge that may be environmentally safe in crop land application. Rapid accumulation of trace metal elements in soils increased the plant uptake of Cd and zinc in plant tissues. At the present time, no phytotoxic effects to the plants were detected.

SLUDGE MANAGEMENT ALTERNATIVES FOR THE LOS ANGELES AND ORANGE COUNTY METROPOLITAN AREA

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LA/OMA Project, Whittier

In the Los Angeles - Orange County Metropolitan Area, there are three major wastewater treatment agencies: The City of Los Angeles, Los Angeles County Sanitation Districts and Orange County Sanitation Districts. In 1976, about 900 dry tons of sludge was produced every day by these agencies. The projection is for this figure to nearly double by the year 2000. In order to avoid duplication of local efforts and examine potential regional systems of sludge management, these three agencies, in conjuntion with the U. S. Environmental Protection Agency and the California State Water Resources Control Board, have jointly developed a Regional Wastewater Solids Management Program for the Los Angeles/Orange County Metropolitan Area (LA/OMA Project).

The LA/OMA Project is charged to develop a long-term sludge management plan, including an implementation strategy. The plan is to provide for reuse and/or disposal of sludge in an environmentally, economically and socially acceptable manner. After careful examination and preliminary evaluation of the known processes for treatment, transportation, disposal and reuse of sludge, eighteen candidate systems were developed by the Project. These candidate systems were analyzed in detail for cost and energy balance. A preliminary identification of environmental concerns was also made. Using this information and the results from ongoing investigative and demonstration projects, LA/OMA Project has formulated six sludge management alternatives. These alternatives are receiving detailed evaluation for the preparation of a Project Report and Environmental Impact Statement. The sludge management alternatives are:

Alternative 1: Long Distance Transport
This alternative provides for the pipeline transport of sludge to areas removed from the urban center for solar drying and/or direct land application.

Alternative 2: Composting - Sludge Recycle Center
This involves the composting of sludge in the urban area and emphasizes its reuse in urban and/or agricultural markets.

Alternative 3: Thermal Processing
In this alternative mechanically dewatered sludge would either be dried or combined with supplemental fuel and then pyrolyzed.

Alternative 4: Ocean Disposal
Alternative 4 provides for ocean discharge of sludge by outfalls in deep canyons or by barge transport with dispersal over large areas.

Alternative 5: Separate Secondary Sludge Processing
Under this concept, the primary and secondary sludges would be processed separately.

Alternative 6: Baseline - "No Project"
This concept is required by the National Environmental Pollution Control Act and the California Environmental Quality Act. Analysis of this alternative will assume secondary processing for all treatment agencies.

CALIFORNIA LAW REGULATING USE OF WASTE AND UNPROCESSED FOOD CROPS

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The federal Food and Drug Administration apprised planners of a significant potential problem regarding the addition of sewage sludge to land not owned by a sewerage agency, when representatives of FDA stated the FDA may establish action levels (maximum permissible concentrations) for cadmium in foods. It follows from findings made by FDA and the Joint Food and Agriculture Organization of the United Nations/World Health Organization Expert Committee on Food Additives that: (1) an increase in the amount of cadmium in foods in the marketplace for consumption by humans should not be permitted; and (2) food from sludge-treated soil that would increase the amount of cadmium in that marketplace should be considered adulterated as defined in California's Sherman Food, Drug, and Cosmetic Law.

Variations in characteristics among sludge-treated soils cause variations in the amount of cadmium which can be taken up by plants. Field experiments are needed to predict cadmium concentrations in crops that would be raised for consumption by humans, on land not owned by a sewerage agency. Controls are being considered by staff of the California Department of Health with respect to: (1) foods to be eaten by humans; (2) addition of sludge to land owned by the sewerage agency; (3) addition of sludge to land not owned by the sewerage agency; and (4) transfer of custody of sludge.

PROPER MANAGEMENT AND USE OF SLUDGE AND WASTEWATER FOR AGRICULTURE AND GARDENS

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The President has been placing increased emphasis on conservation of energy and resources. The Congress and EPA have been placing increased emphasis on applying wastewater and sludge nutrients onto land to conserve energy and resources through new policies (Land Treatment Policy Statement, October 1977) and laws (Clean Water Act of 1977, PL 95-217 and Resource Conservation and Recovery Act of 1976, PL 94-580).

A number of research groups have been studying techniques for safe handling and recycling of sludge and wastewater. A number of regulatory authorities have been drafting and promulgating regulations to assure safe recycling. A problem arises in deciding upon what is a sufficiently safe course of action at a reasonable cost and what are reasonable risks compared with being overly protective and restrictive to reduce or eliminate risks completely at far greater costs. This is not an easy task.

Historically where properly managed systems have been used for crop production, beneficial effects on soils and crops have resulted with no apparent health problems. While there are certain risks associated with land application of wastewater and sludges, there are also risks associated with other treatment alternatives. Study and work is continuing by EPA and many other groups to minimize these risks. Good management is a most important element. Recent pertinent EPA policy, guidance and regulations will be mentioned and examples of success sludge and wastewater utilization/recycling will be given.

NITROGEN MANAGEMENT IN IRRIGATED AGRICULTURE - AN OVERVIEW

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Nitrogen constitutes approximately 29 percent of our atmosphere and has been estimated in the amount of 10^{15} tonnes in the soils, water, plants, animals and air of the earth. Even with so great an amount present the general case is for the forms of nitrogen required by plants to achieve maximum growth to be deficient in an agricultural production system. Consequently, nitrogen fertilizer inputs are essential to meet our food and fiber production needs.

Since agriculture does not exist independently of all other segments of society, it shares the concerns of others with regard to protection and conservation of energy, land and water resources. So, agricultural scientists have become engaged in finding ways to use nitrogen fertilizer that will meet our food production needs and at the same time prevent unwanted entry of nitrogen into the environment. In order to achieve those goals for irrigated agriculture we are using our knowledge of climate, soils, plants, the nitrogen cycle, and irrigation methods to understand more fully how various techinques of nitrogen and water management can be used to produce food and prevent nitrogen accumulations where it is not wanted.

We already know much about nitrogen use in an agricultural crop production system, for instance; a plant is genetically not capable of removing all the nitrogen from a soil profile; some nitrate-nitrogen is continually being formed in an agricultural soil through decomposition of organic matter; in irrigated agriculture some water must leach through the soil profile to prevent salt buildup; all these factors contribute to the fact that where plants are grown in a soil-water system, some leaching of nitrogen to surface or ground waters is inevitable. This process has been going on since the beginning of time. However, it has become clear from recent years of research effort that those management techniques which contribute to the most efficient use of nitrogen regardless of source allows the achievement of both goals, food production and environmental protection.

Research has shown that for any given set of conditions such as climate, soil and crop at a particular location, a peak nitrogen use efficiency can be achieved by adjusting nitrogen application rate, timing, fertilizer application in relation to plant demand, placement of the nitrogen in the root zone, selection of the proper source of nitrogen, and improved water management. The effect of these efforts is to reduce the amount of nitrogen carryover to a level approximately the same as if the crop had not been grown or nitrogen fertilizer had not been used. Therefore, food production can be maintained and the environment protected by efficient use of nitrogen fertilizer and an additional benefit is conservation of our land, water and energy resources.

UTILIZATION OF SOIL AND FERTILIZER N - CORN

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In the early years of this decade, kilogram quantities of ^{15}N depleted $(NH_4)_2SO_4$ became available at reasonable cost, making large field-scale experiments using tracer N feasible. Partially financed by NSF grants, two field trials utilizing corn under sprinkler irrigation were set up, one at Davis, the other at the Kearney Horticultural Field Station near Fresno. Among the differences between these two experiments, the Kearney soil allowed only shallow rooting and was low in OM and N while the Davis soil was deep with a high residual of soil N. These experiments were designed primarily to test the feasibility of using nearly pure ^{14}N as a tracer in large scale field experiments and to trace the fate of fertilizer N into plants, soil, and drainage water.

Irrigation was tightly controlled at 1/3, 1, and 5/3 ET at Davis and 1.1ET at Kearney. Fertilizer rates were 0, 90, 180, 360 kg N/ha and 0, 112, 224, 336, 448, 560 kg N/ha at Davis and Kearney respectively and were replicated 4 times. Main plots were fertilized every year for 5 years at these rates with ^{14}N tagged fertilizer side dressed at planting time. Some sub plots were tagged only certain years. Drainage water, soil samples, and plant parts were taken periodically and analyzed for appropriate constituents. N samples were also analyzed on a mass spectrometer to determine $^{14}N/^{15}N$ ratios and percentage of tagged N in the sample.

Maximum yields at Kearney were obtained at the 224 kg/ha fertilizer rate for all years while the 0 rate produced very little--only 15-20% of the maximum yield. At Davis, there was no fertilizer response the first year but by the third year, maximum yield was attained at the 180 kg/ha rate.

When various plant parts (at silking) were analyzed for fertilizer derived N, a top to bottom gradient was found in N deficient plants but not in N sufficient plants. At the 112 kg/ha rate, 56% of the N of the bottom leaf was fertilizer derived, but only 44% of the top leaf N came from the fertilizer. By contrast, at 560 kg/ha, 85% of leaf N was fertilizer derived with no appreciable gradient from top to bottom. Internode pith showed a gradient opposite to that of the leaves, with 37% at the bottom and 46% at the top at the low fertilizer rate. However, there was a remarkable uniformity of fertilizer source among types of parts of a given plant when all of the plant was considered, i.e., all the leaves compared with all the nodes, internodes, silk, tassle, or cob regardless of nutrient status of the plant. On the other hand, if the N source were followed in a plant as a function of time, a drop was found in the percentage of plant N derived from the applied fertilizer as the season progressed. For example, at the Kearney plots with 224 kg N/ha (1973) corn leaves at 40 days after planting derived 79% of their N from the tagged fertilizer, but this dropped to 65% 120 days later. The inference is that early in the growth cycle the roots of the young corn plant are exploring primarily shallow soil horizons and picking up mostly drilled fertilizer, but as the plant grows, the roots expand into volumes of soil with little or no fertilizer and pick up proportionately more native soil nitrogen.

Nitrogen uptake efficiency can be defined as the total amount of N found in the plant divided by the N added in fertilizer. By this definition Kearney corn returned 101% to 117% to the plant at rates up to 224 kg N/ha, the rate of maximum yield. Beyond this rate, however, little extra N was taken up indicating little luxury consumption and uptake efficiency dropped to 45% at 560 kg N/ha. If, however, we define N uptake efficiency as that portion of added fertilizer which actually appeared in the plant (i.e., tagged fertilizer N), then we have a different picture. Only 61% of the fertilizer N appeared in the crop at 112 kg N/ha, 67% at the 224 rate then dropped to 35% at the 560 rate. The picture was somewhat different at Davis because of the relatively greater native soil N at that site. Gross N efficiencies ranged from 185% to 220% at 90 kg N/ha (for the 1 ET irrigation regime) but dropped to 60% to 80% at the 360 rate. As at the Kearney site, however, the fertilizer uptake efficiency was much lower. Again for the 1 ET irrigation regime, fertilizer uptake efficiency at Davis ran from 63% to 68% at the rate just sufficient to give maximum yield and dropped to 35% to 45% at the highest fertilizer rate. It should be noted that while fertilizer uptake efficiency was nearly the same at the two sites, the gross N uptake efficiency was about twice as high at Davis compared to Kearney due to the greater soil N uptake at Davis. It is important here to note that maximum fertilizer uptake efficiency always occurred at the fertilizer rate just sufficient for maximum yield regardless of the site or year.

By means of tracer methods, native soil N uptake (as opposed to fertilizer N uptake) can be measured directly and is not hampered by assumptions made by using the difference calculations of non-tracer methods. At Kearney, 34 kg/ha of native soil N was taken up by the plants in the check plots, running up to a maximum of 80 kg N/ha for the 224 kg N/ha fertilizer rate, then dropping to 53 kg N/ha at the highest fertilizer rate. The absolute uptake at the Davis site was 1 1/2 to 2 times as much, but here again, the maximum utilization of native soil N at both sites and all years was at that fertilizer rate which just produced maximum yield.

When crops are fertilized by a tracer N fertilizer one year and a standard, non-tracer fertilizer the next year, N carry-over effects can be determined directly. In several experiments of this kind, it was found that only 3% to 8% of plant N was from the fertilizer of the previous year. It should be noted that the crop under question, the second year crop, was fertilized at the full fertilizer rate rather than being left unfertilized. This kind of information can be gained only by tracers.

Since only 35% to 68% of the added fertilizer in these experiments was taken up by the plant, the question arises as to the fate of the remaining N. Briefly, N balance calculations at Kearney show an unaccounted for loss of N, over a three year period of 16% to 25% of the total added. This is presumed to be gaseous loss due to denitrification. Further, at Kearney where the soil is low in OM and all stover and cobs (but not grain) were returned to the soil, tagged N was traced into the soil OM. After just 2 years, 16% of the soil organic N was fertilizer derived in plots at the 560 kg N/ha fertilizer rate. By contrast, it was difficult to trace fertilizer N into the organic fraction at Davis because of the large organic N pool and the fact that neither stover nor grain were returned to the Davis plots after harvest. Leaching below the root zone is a third mode of fertilizer N loss to the crop. This fertilizer N loss increased in all cases with increasing rates of fertilizer, as one might expect. These increases were relatively small, however, up to the fertilizer rate of just maximum yield but increased rapidly at rates beyond that point.

These studies have demonstrated the practicality of using ^{15}N depleted N fertilizer for tracing N in large field studies. A difficulty of doing N efficiency studies without tracers and using yield as a criterion is that one must work on the slope of the yield curve in order to obtain a response. This results in using a below optimum plant-soil system and one which is abnormal compared to a system with full yield potential. Tracer technique allows testing of fertilizer placement, timing, form, etc. by means of fertilizer uptake into a plant at its maximum yield. These studies should open the way for more effective N efficiency studies in the future. They have shown that it is possible to obtain full yields at high fertilizer efficiency and with minimal potential for pollution to the underground waters.

UTILIZATION OF SOIL AND FERTILIZER NITROGEN BY SUGARBEETS

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Nitrogen uptake by sugarbeets (Beta vulgaris L.) from fertilizer, related to time and rate of application, was evaluated at Davis, California in two field experiments in 1975 and 1976 on Reiff and Zamora loam soils, respectively. In both experiments ^{15}N-depleted ammonium sulfate (0.003% ^{15}N) was utilized as tracer nitrogen.

When 135 kg N/ha was applied: split equally between planting, thinning, and layby; all at planting; all at thinning; or split equally between thinning and layby, there was a large response to fertilizer N but there were no significant differences in root and top yields among fertilized plots. Also, there were no important differences in fertilizer uptake among fertilized plots. The tops and roots from all fertilized plots averaged 20.6% N derived from fertilizer. The amount of fertilizer N in the crop represented a recovery of 37.4% of the fertilizer applied. Based on results with these soils, where irrigation water was carefully applied by furrow to about equal water used by evapotranspiration, it appears that sugarbeets can be fertilized with nitrogen from planting to mid season without seriously affecting the efficiency of uptake of fertilizer N.

To determine the effect of the rate of fertilization on N uptake, six N rates: 0, 56, 112, 168, 224, and 280 kg/ha, were applied. Maximum sugar production occurred with the addition of about 112 kg N/ha and at that rate 47% of the N applied was recovered by the crop. In studies with corn (Zea mays L.) at Davis in 1975 and 1976 on a Reiff sandy loam soil (Broadbent, unpublished), about 65% of the N from the fertilizer rate giving maximum grain yield was recovered by the crop. Thus, in these experiments, sugarbeets exhibited less dependency on fertilizer N and a greater use of soil N than was the case with corn. An understanding of the comparative abilities of crops to utilize fertilizer and soil N should contribute to the establishment of rotation systems to improve the efficiency of fertilizer use and minimize nitrate pollution of groundwater.

When sugarbeets were fertilized for maximum sucrose yield, as much N was removed in roots as was applied (Figure 1). Removal of tops resulted in the removal of additional N. Even when fertilized at 2½ times the rate required for maximum sugar yields, tops and roots removed almost as much N as that applied as fertilizer (Figure 2).

A key to efficient fertilizer use is the development of soil and plant analysis techniques for use in commercial production that will result in the use of rates of fertilizer N close to those required for maximum yield for each crop and soil. For sugarbeets, plant and soil analysis procedures have been developed for this purpose. Their widespread use is highly desirable.

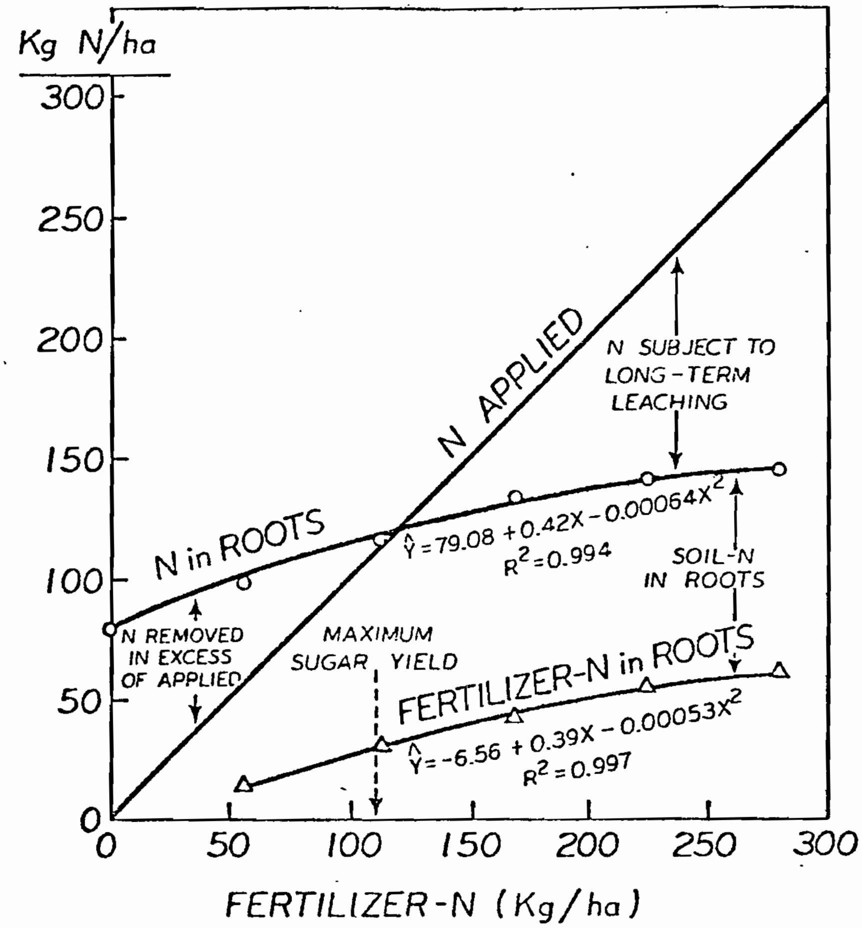

Figure 1. Effect of applied N on the amount of N in sugarbeet roots and on N subject to long-term leaching.

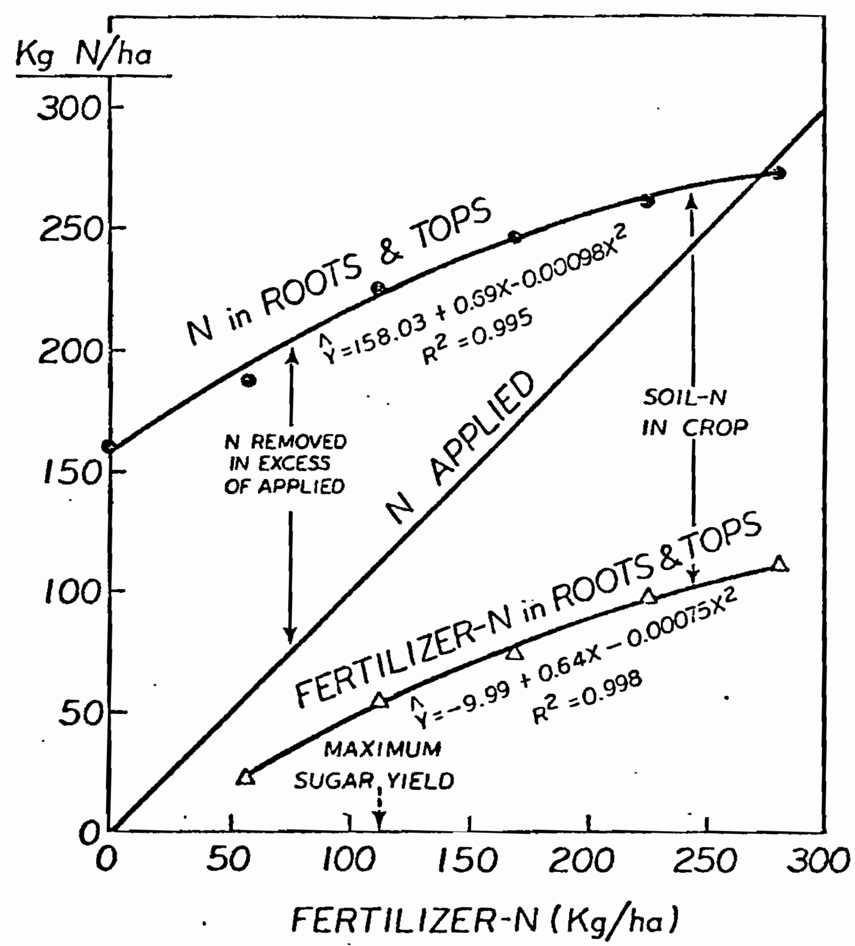

Figure 2. Effect of applied N on the amount of N in the sugarbeet crop and the potential for removal of N in excess of that required as fertilizer.

NITROGEN RATES AND TIMING IN FRUIT TREES

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Fertilizer experiments have been established in many orchards in many areas of the state off and on since 1920, and perhaps before. Yields and cultural practices have so changed since then that most of the early data may not be valid today. Two studies completed within the past ten years and three in progress provide fairly sound guidelines for nitrogen use in mature orchards.

Between 1966 and 1969 inclusive, a multi-variable study was carried out in a cling-stone peach orchard in the Wheatland area of Yuba County. Ammonium sulfate was used as the N fertilizer at the following rates: 0, 0.75, 1.5, 3.0, and 6.0 pounds actual N per tree. After four years, overall maximum marketable yields occurred at the 0.75 and 1.5 pounds N rates. Below and above these nitrogen amounts, yield was less as a direct result of smaller fruit sizes.

In a rate, timing, incorporation vs. surface application of urea in a Modesto peach orchard, the results may be comparable. After two years, a trend exists for the zero nitrogen rate to outproduce the 40, 80, 120 and 160 pounds of N per-acre-per-year rates. We do not expect this to continue. The implication thus far is excessive amounts, 150 N per acres, were being used prior to starting the study. The lowest yields are from the highest rates, 160 pounds N per acre. A complicating factor was a cannery strike one year into the trial caused a heavy crop, containing 60 pounds or so of nitrogen per acre to go back into the soil.

A Tilton apricot orchard in the Westley area of Stanislaus County served as an ammonium sulfate rate trial between 1968 and 1971. Surface applications were hand-spread under each tree at the rates of 50, 100, 200 and 400 pounds of N per acre per year. Marketable yield was not increased above 100 pounds N per acre. Fruit maturity was delayed two to four weeks at the 400 N rate and, as such, was too late for cannery use.

A nitrogen rate trial has been underway in a Butte County almond orchard for the past four years. Urea is being used at the rates of 0, 56, 112, 224 and 448 pounds N per acre per year. The 224-pound rate appears to be the rate to use.

Another almond nitrogen rate trial is now into the second year near Turlock. Ammonium sulfate, at rates of 100, 200, 300 and 400 pounds N per acre, incorporated and spread on the surface was applied in October 1976. As expected, the harvest of two varieties in 1977 showed no differences.

These studies, that are statistically sound, have shown that if trees are receiving enough nitrogen, yield differences will not be seen in the crop following establishment of rate differences. If nitrogen is not being used at an adequate rate, an increase might be seen within the year. The point here is that timing of nitrogen applications is often of little consequence, but not always.

Timing may be important if trees have not been getting enough N, and a yield increase is wanted rapidly. Current thinking is that in such cases the nitrogen should be applied in time for root uptake before leaf fall. We do not as yet have yield data from commercial orchards where timing affected maximum crops.

In orchards where early harvest is a major consideration, nitrogen levels are maintained at minimum levels, and time can be important. A classic example is shipping apricots in the Winters area of Yolo County. Nitrogen applications are applied shortly after harvest. To wait until autumn or winter will cause harvest to be delayed. Where maximum yield is the major consideration, higher levels of N are used, and timing is generally a matter of other considerations.

In the Yuba County peach orchard and the Stanislaus apricot orchard, ammonium sulfate applications were spread on the soil surface by hand.

Winter rains were relied upon to move the N into the root zone. Volatility losses were not under evaluation at that time. In the continuing trials in Butte County almonds, urea is spread on the surface and immediately watered into the soil by sprinklers.

A major purpose in the almond and peach N studies in Stanislaus County is to evaluate volatility losses. Urea is either incorporated or left spread on the surface in November. Ammonium sulfate is also used as a surface treatment in the almond orchard. Data being obtained includes winter twig and summer leaf samples for N analyses. Thus far, there is an indication that some loss of nitrogen has occurred from the November surface application. Soil samples are monitoring leaching losses, if they do occur. Of course, yields will tell the economic story, but to date nothing conclusive has developed.

Attempts were made in 1976 and 1977 to use the growth rates of newly planted trees as a means of getting volatility losses from several forms of nitrogen. Rates as low as one-half ounce of ammonium sulfate per tree during the first summer are too high to detect losses. During 1977, eight species of trees were used and rates of ammonium sulfate were 0, 5, 10 and 15 (approximately 1/2 ounce) grams per tree. Equivalent nitrogen rates were used in the forms of urea, calcium nitrate, 16-20-0, 15-5-25, etc. The materials were either spread or ringed on the surface or incorporated on both wet and dry soils. An overriding factor of lack of soil moisture shortly after planting nullified growth data.

In summary, nitrogen rates for processing apricots and peaches is in the range of 75 to 150 pounds per acre per year, with shoot growth as a visual guide. July leaf values for nitrogen in canning apricots should be 2.5 - 3.0 % and peaches should be in the range of 2.6 to 3.0. Shipping apricot leaf values are lower, 2.0 - 2.5 % and the same is true for shipping peaches and nectarines, 2.5 - 2.8 % N in July. Almonds can beneficially use

N in the 200 to 225 pounds per acre range. July leaf values for almonds should be in the range of 2.4 to 2.6 percent. Walnuts can produce top yields with 175 to 200 pounds of nitrogen per acre and July leaf values of 2.2 - 3.2 % N. This latter recommendation is based on yield and N rate records, but this is from grower records.

Orchards reported on in this paper have yield records that place them in the top 10 percent. In such orchards, a change of timing nitrogen applications from one part of the year to another is of no or little consequence as far as yield is concerned.

STRAINS OF RHIZOBIA FOR ALFALFA AND OTHER LEGUMES IN CALIFORNIA

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Alfalfa, medicago sativa, is grown in California from the extreme northern boundary to the southern boundary. The weather patterns under which it is grown varies considerably. The varieties of alfalfa grown are also different with the dormant grown in the north and non-dormant in the valleys and warmer areas. With all of the varieties of alfalfa which are grown it would appear that the rhizobia might also vary. Thus the purpose of this study was to determine the variability of the interaction between Rhizobium meliloti and its host alfalfa.

Our results indicate that there is a host specific interaction between R. meliloti and specific varieties of alfalfa. The interactions range from a parasitic to highly effective. Studies reveal several bacteria are apparently adapted to particular environment. For example some acid tolerant strains will not grow under near neutral conditions, some appear to be not only acid tolerant but growth also occurs at neutral pH. Some produce acid in culture but most do not.

These factors help determine which strains will be used in field trials. Results of field trials will indicate which strains of R. meliloti are the most effective for commercial inoculants.

PRODUCING SOYBEANS IN CALIFORNIA

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The commercial acreage of soybeans in California has increased from five acres in 1973 to over 10,000 acres in 1977. The majority of these soybeans were planted from mid-June to mid-July as a double crop following the harvest of winter cereals. The increased value of soybeans in recent years and the emphasis on using them in a double crop situation may make the crop a successful addition to field crop rotation patterns in California. While the potential of this crop is being studied in many areas of the state, the information presented here will deal with soybeans grown on the east side of the San Joaquin Valley.

Williams and Amsoy 71 have been the two varieties most frequently planted in commercial fields. These varieties reach harvest maturity 120-130 days after planting and have yielded well both in research plots and in growers' fields. Studies on row spacing and plant population with the variety Williams have shown yield potential over 4,000 pounds per acre (66 Bu/A) on 12" rows and a population of 140,000 plants per acre when grown as a double crop after barley (table 1). The highest yield obtained in a commercial planting was 3,657 pounds per acre (61 Bu/A). This field of Williams was planted with a grain drill (7" spacing) following the harvest of wheat.

Grower yields have ranged from 1,000 to over 3,000 pounds per acre. Table 2 gives the yields of five growers who planted soybeans as a double crop following the harvest of barley or wheat. The planting dates ranged from June 15 to July 15. These growers used several different methods of planting, irrigation and other cultural practices. Low yields were obtained in fields with 38" or 30" row spacing and low plant populations (less than 70,000 plants/A). The growers who obtained the highest yields (with either Amsoy 71 or Williams) had closer row spacing and higher plant populations. In addition to having excellent plant density, these growers had few weeds and did not stress the plants for water during the season.

In 1975-76, harvest losses assessed in several commercial fields ranged from 62-580 pounds per acre. Harvest losses were primarily due to pods set too low to the ground and uneven ground (especially in bed plantings). Shatter, often considered a major limiting factor in soybean production in California, is minimal with the varieties Amsoy 71 and Williams when planted mid-June to mid-July. Harvest losses were minimized where close row spacing, high plant population and flat plantings were used. This resulted in the fewest pods near the ground and allowed the cutter bar to be set close to the ground. In 1975 harvest losses averaged 397 pounds per acre (17% of the total yield) where the soybeans were furrow irrigated; this compared to 251 pounds per acre (9.7% of the total yield) where the crop was planted on the flat and flood irrigated.

In 1976, a September rain did not adversely affect the seed quality. Soybeans harvested at maturity (125-130 days after planting) had excellent seed size, oil and protein levels and appearance. Those soybeans that were not harvested until after an extended period of fog (about 20 days in November) had good size and protein. They did, however, have more splits, blemished seed coats and an overall poorer appearance than those harvested earlier. These soybeans were acceptable for crushing purposes but would not be suitable for a certified seed or the edible soybean market.

The marketing of soybeans grown in California has developed rapidly along with the increase in acreage. Several commodity brokers have indicated an interest in soybeans in California. The majority of the acreage (over 10,000 acres) grown in 1977 was contracted by the grower prior to planting. Most of the contracts were on an acreage basis, not actual tonnage. Growers received from $200-250 per ton in 1976-77 seasons. The attractive price and the contract on an acreage basis provided encouragement to new growers in this trying crop. A cost study survey conducted in 1976 showed the growers' cash cost for soybeans planted as a double crop ranged from $80.04 to $162.25 per acre. Several growers also included the cash costs for two other double crops grown in the San Joaquin Valley, corn silage and milo. In each instance, the cash costs for these crops were $25-30 per acre <u>higher</u> than soybeans. The additional costs were due to: (1) higher water usage; (2) use of nitrogen fertilizer; and/or (3) drying costs (milo) at harvest.

Spider mites have historically been considered the major pest problem of soybeans in California. Grower fields in 1975-76 were surveyed for mites and other insects on a weekly basis. In 1975, most growers controlled mite populations using a preventative approach -- applying a miticide before economically damaging levels were reached. In 1976 and 1977 growers began to utilize chemical control methods only if the situation warranted it based on the weekly field evaluations. Of the surveyed fields, less than 25% were treated with a miticide. This successful use of field survey techniques to determine the extent of mite and other insect infestations was an effective method of minimizing the need for chemical pest control measures. In summary, spider mites have not been a limiting factor in the growing of soybeans as a double crop on the east side of the San Joaquin Valley. With few exceptions other insect pests did not reach damaging levels in the fields surveyed. Registration of miticides for use on soybeans is still a problem, but efforts are being made toward obtaining registration.

While the growers in the San Joaquin Valley have planted only the varieties Williams and Amsoy 71, there is a continuing need for better varieties that are adapted to California conditions. Table 3 gives a summary of the yield and seed quality of some of the varieties tested in trials conducted in 1976 and 1977. There is a definite need for new varieties in California that have some or all of the following characteristics: (1) higher yield potential than Amsoy 71 and Williams; (2) maturity reached in 100-110 days rather than the 125-130 days for Williams and Amsoy 71; (3) lodging resistance; (4) good seed quality; (5) bottom pods set high (6-8 inches) off the ground; (6) spider mite resistance; (7) shatter resistance (8) salt tolerance; and (9) a determinate type of growth. There are several other characteristics that could be listed in addition to these.

Several other studies have been conducted by the author and cooperating researchers on diseases, fertilization, irrigation, weed control, and other aspects of soybean production. Cooperating researchers included Dr. C. Summers, Dr. D. Gilchrist, Dr. J. Hill, Mr. V. Burton and Mr. J. St. Andre of the University of California; Dr. B. Beard of USDA, and Mr. Cavanagh of Ranchers Cotton Oil.

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TABLE 1 - The effect of row spacing and plant population in the yield potential of Amsoy 71 and Williams planted mid-June following barley. Tulare County, 1974-77.

ROW SPACING	PLANT POP. PER ACRE	Yield (lb/A) /a AMSOY 71 1974	AMSOY 71 1975	AMSOY 71 1977	WILLIAMS 1975	WILLIAMS 1977
12-13"	94,000	----	2725	2338	3328	2729
12-13"	140,000	----	2389	2595	4027	2719
20"	94,000	3079	3503	2676	3392	2606
20"	140,000	3545	3079	2599	3144	2832
30"	94,000	2928	3203	----	2774	----
30"	140,000	3066	3046	----	----	----
40"	94,000	2891	2577	----	2739	----
40"	100,000	2847	----	----	2357	----

/a - Yields adjusted to 13% moisture

TABLE 2 - Soybean yields obtained by five growers in the San Joaquin Valley. The varieties Williams and Amsoy 71 were planted as a double crop following barley or wheat 1975-77.

GROWER	DATE	ACRES	ROW SPACING	METHOD OF IRRIGATION	YIELD /a lb/A	YIELD /a bu/A
A (Visalia)	1975	29.0	38"	Flood	2,316	38.6
	1976	29.0	38"	Flood	2,073	34.6
B (Dinuba)	1976	18.5	38"	Flood	2,074	34.6
	1977	20.5	2 rows on 38" center	Furrow & Sprinkler	2,400	40.0
C (Hanford)	1975	35.9	30"	Flood	2,451	40.9
	1976	212.0	30"	Flood	1,993	33.2
D (Hanford)	1975	16.1	10"	Flood	3,146	52.3
	1976	145.0	10"	Flood	2,749	45.8
E (Tulare)	1975	6.0	2 rows on 40" center	Flood	3,055	50.9
	1976	32.0		Flood	2,772	46.2
	1977	40.0		Flood	2,540	42.3

/a Yields are based on weight tickets rec'd by growers; moisture varied from 8-15%

TABLE 3 - Yield and seed quality of soybean varieties planted mid-June as a double crop following barley. Tulare County, 1976-77.

	YIELD (pounds per acre) /a		SEED QUALITY /b		
VARIETY	1976	1977	OIL	PROTEIN	SEED SIZE (gm/100 Seed)
Amsoy 71	2590	2556	20.5	35.5	19.8
Beeson	2104	2175	18.6	38.7	21.1
Calland	2487	3293	18.5	37.4	22.0
Columbus	2296	2841	19.1	37.5	15.5
McCoy 1100	2485	2987	19.5	36.6	19.6
SRF 200	2957	2199	20.5	34.5	16.6
SRF 307	2735	2765	18.6	37.1	17.6
Wells	1591	2611	18.8	38.6	17.0
Williams	2979	3073	18.3	38.2	20.8

/a - Yields adjusted to 13% moisture.

/b - Data from 1976 only

MAXIMIZING COTTON YIELDS PER ACRE FOOT OF WATER

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Most of the cotton grown in California is grown in the San Joaquin Valley. Irrigated agriculture in the San Joaquin Valley has already expanded beyond the long-term supply of water. Underground supplies are being depleted. Sooner or later we will need to either import more water to satisfy our present agriculture or reduce the area of irrigated land.

While there is a desperate need for irrigation water, there are ironically, several thousand acres of land with a perched water table within 8 feet of the soil surface. The problem with this shallow groundwater is that it is highly saline.

This water cannot be collected in drains and reused on the surface for irrigation because it is too saline and contains an excessive amount of boron. However, Bernstein and Francois (1) in their studies, pointed out that plants can tolerate much greater salinity at the base of the root zone than previously believed to be safe. Field work during the last two years has been aimed at turning this saline shallow groundwater into somewhat of an asset instead of a total problem.

In 1976, a preliminary cotton irrigation trial was conducted in a field with tile drains set at 8 feet. The water table stood between 6 and 7 feet. The electrical conductivity (EC) of the drain water ranged from 4.0 to 6.0 millisiemans/cm (mS/cm).

All plots were pre-irrigated to wet the soil above the water table to field moisture capacity. This required only about 10 inches. However, a greater volume was applied with the excess going through the profile to the drain system. Each treatment was 12 rows wide (40 feet) and 2580 feet long and laid out in randomized complete blocks of four replications. The center four rows were harvested and weighed. The yield results are shown in Table 1.

Table 1.

Irrigation Schedule	Water Applied (inches)	Yield (lint/ac.)
A. Pre + 7/10	13	1104 pounds
B. Pre + 7/10 & 7/30	16	1015 "
C. Pre + 7/10, 7/30 & 8/19	19	991 "
D. Pre + 7/20 & 8/19	18	973 "
		LSD @ 1% 33 "

All growing season irrigations were in alternate middles with 3 inches applied each time except for July 20 irrigation in treatment D where 5 inches were applied.

Cotton actually tr spires about 27 inches of water per season. Even if 100 percent efficiency of irrigation is assumed, these cotton plants extracted about 14 inches of water from the water table.

One of the concerns of reduced leaching and using perched water as a water supply is the possibility of accumulating excessive salts in the soil profile. This was monitored in these trials and presented no problem.

Cotton is relatively tolerant of salinity. Ayres and Wescott (2) and Maas and Hoffman (3) in recent summaries fix the maximum electrical conductivity of the saturated soil extract (EC_e) for cotton at 27 mS/cm. Since the EC_e is approximately two times the EC of the soil water at field moisture capacity the plants actually use water with an EC of 54 mS/cm and above.

Where groundwater is within reach of the plant roots, capillary action keeps the soil moisture within the lower root zone greater than the field capacity. The soil at the water table is, of course, saturated. This means that the soil water immediately above the water table could have the same EC as the soil having the maximum allowable EC_e. From this I conclude that the conductivity of the water in the tile drain could approach two times 27 or 54 mS/cm. It probably would be foolhardy to permit the leaching fraction to be so low that the drain water would reach this figure but certainly it could be permitted to go to a level considerably greater than now found. If this careful use of shallow water is adopted it will substantially increase the duty of water brought into the area for irrigation. It will also reduce the total volume of water that needs to be placed into the drains and taken out of the area. The drainage water, however, would be considerably more saline.

In water short areas without shallow water, there are a number of ways water can be more efficiently used.

All too many growers apply excessive amounts of water in the preplant irrigation. Any pre-irrigation in excess of 12 inches is probably excessive. Even though a clay loam soil may hold as much as 15 inches of available water in the cotton root zone, the entire profile is seldom if ever at the wilting point. The most common reason for these large applications is lack of control because of too long an irrigation run. Shorter runs may increase labor requirement but would save much water. It may even pay to convert to sprinkler irrigation when the price of the added irrigation water is taken into account.

Another source of waste is the application of a crop irrigation in late May or early June when the cotton has used only two or three inches of water. Some of the water applied then goes to deep leaching. By most furrow methods of irrigation there is no reasonable way of applying "just a little bit".

Irrigations applied too late in the season may be not only wasteful but can lead to delayed maturity of the crop. The last crop irrigation should be applied so that the available soil moisture is removed by mid-September (see Figure 1).

Grimes et. al. (4) determined that by using good field irrigation practices the maximum cotton yields were obtained by applying 38 inches of water (see Figure 2). Somewhat less than maximum yield is economically desirable as determined by water cost and expected return from the crop. The maximum yield per unit of water is at 21.8 inches applied. This also is an uneconomical amount to apply since all of the productions costs are already invested except for the additional irrigations and extra ginning costs. About 34 inches is probably the optimum amount to use. There is no way to economically stretch the use of water by taking a somewhat lower yield over greater acreage. This is true even if you account for the costs involved in leaving land fallow. If you know how much water you will have available, pre-irrigate and plant only that land that you can irrigate most efficiently throughout the season and fallow the rest.

Skip-row cotton will not increase your water use efficiency. The only situation when skip-row cotton is suggested is if a grower has pre-irrigated more land than he can subsequently fully irrigate.

To get the most out of the available water:

1. Use perched water if available.
2. Avoid excessive deep leaching by improving efficiency of application.
3. Apply water only if the plants need it, but avoid moisture stress during bloom period.
4. Apply last crop irrigation early enough so soil moisture is depleted by mid-September.

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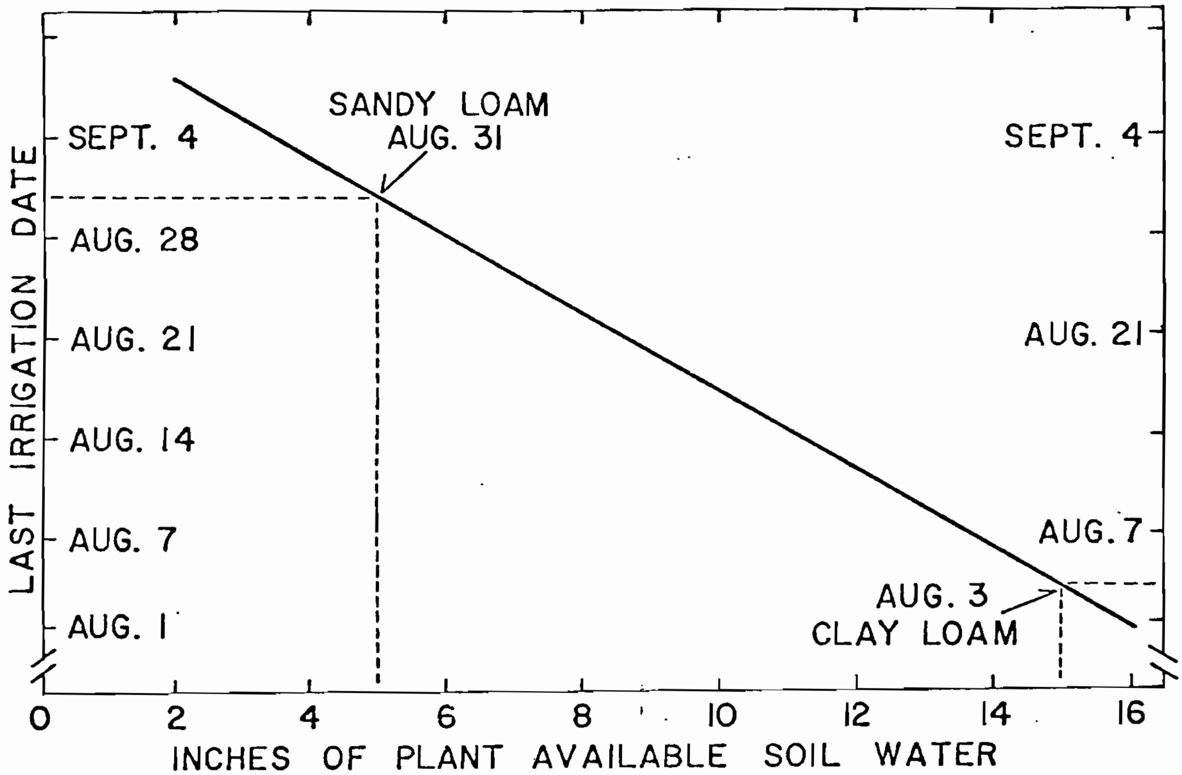

Figure 1. Optimum date of last irrigation for cotton as estimated from available water holding capacity of soils.

From Grimes and Dickens (5).

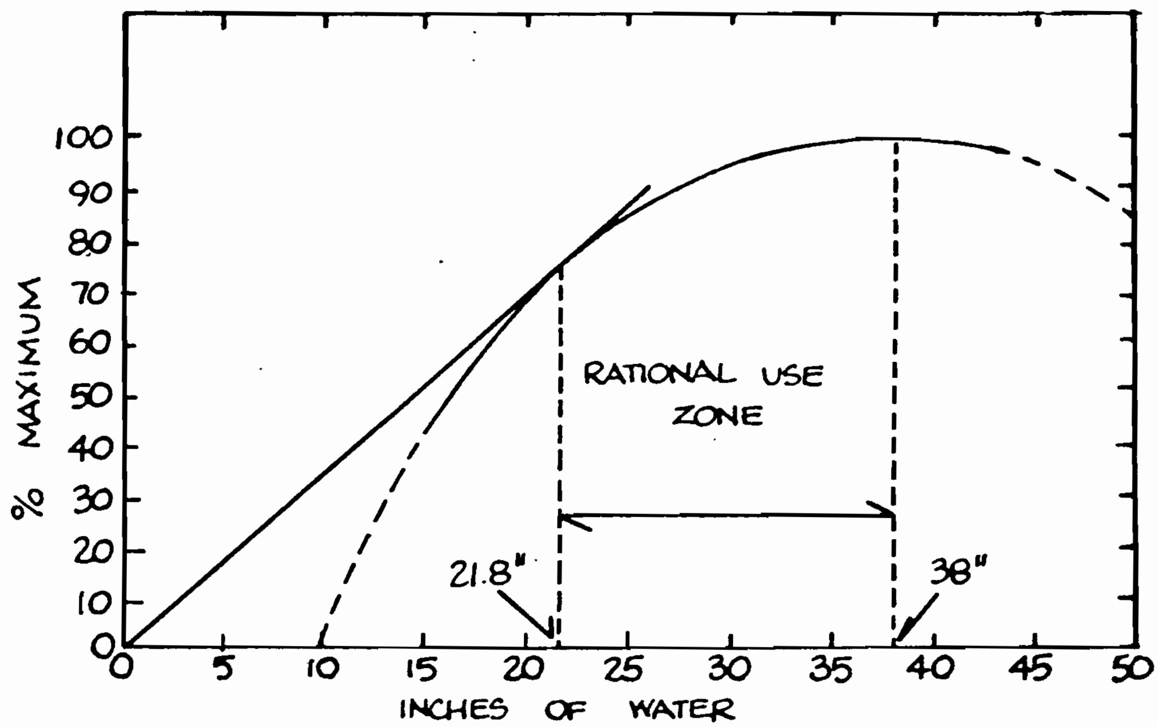

Figure 2. Production of cotton as affected by amount of applied irrigation water.

Adapted from Grimes et al (4).

RESOURCE MANAGEMENT TO MAXIMIZE PROCESSING TOMATO QUALITY

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In addition to ton per acre yields, processing tomatoes can be assessed for quality factors such as solids, acidity, flavor, color, viscosity and firmness; which translate directly or indirectly into processed yield advantages.

Although the canning industry does not pay directly for improved quality, there is still an advantage to the grower to produce a premium quality product. In the first place, although no premiums are paid for exceptional quality, poor quality opens the possibility of rejected loads or economic penalties for failure to meet certain minimum standards. Second and perhaps more important is that proper management practices to produce higher quality are for the most part the same practices which reduce the growers risk due to glut, mechanical damage, sunburn and sunscald. High processing quality is usually synonymous with uniform and concentrated ripening, which in almost all cases means more net dollars in the growers account because of less sorting losses and more efficient harvest operations.

The manageable resources available for the amelioration of processing quality are soil, water, genetic adaptation, fertility, plant growth regulators, herbicides and pesticides. Climate must also be regarded as a resource from a general standpoint and as a factor in management decisions. We are unable to alter the immediate crop climate however, except in a minor way. Examples that come to mind are frost prevention measures or practices designed to negate detrimental effects of climate such as "sun guard" sprays to lessen heat and radiation damage and fungicides to retard mold development.

PLANT EXPLORATIONS, THE PLANT INVENTORY, AND THE TECHNICAL COMMITTEE

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A considerable part of the natural wealth of the United States must be counted as the crop plants we grow and these are literally introduced plants.

The USDA, since its foundation in 1862, has actively procured plants from over the world and has catalogued all collections as the massive plant inventory now numbering nearly a half a million entries.

Plant materials are obtained through direct exploration by plant collectors in areas of genetic diversity; by Public Law 480 funds to hire collectors in specific areas; by exchange; by gifts, donations, or outright purchase. This germ plasm is made available to researchers through four regional plant introduction stations. Each of these stations is responsible for certain plant genera, distributes and repropagates them.

The regional stations work in close cooperation with the State agricultural experiment stations through technical committees. Each of four committees meet annually and is composed of one member from each of the cooperating federal agencies, an administrative advisor, and one member from each State of the region. Technical committees provide liaison with researchers in use of new plant germ plasm, solicit requests for foreign or domestic exploration; assesmbles results of plant evaluations and utilization of the germ plasm. Budgets for the regional plant introduction stations are reviewed and voted upon at the annual meeting.

Valuable agronomic, horticultural, and speciality crop germ plasm eventually may be placed in the National Seed Storage laboratory at Fort Collins, Colorado. At this facility only seeds of high viability are stored under excellent environmental conditions. This repository of several world collections of major crops and many special items is a safeguard to major crop failure in preserving valuable germ plasm for development of new varieties.

By continuing introduction, evaluation and preservation of plant germ plasm of all kinds we may face the future with great courage and readiness to solve the problems sure to come.

COLLECTING GERMPLASM

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Factors dictating a need for germplasm collections are: 1) the rapid disappearance of local materials when superior varieties are introduced; 2) the pressure on agriculture from increasing populations that requires concentration on high energy crops; 3) urbanization that decreases interest in foods of local interest; and 4) improved transportation that moves seeds over long distances. Herbaria have provided useful information on when and where to collect, and have often described local uses of a plant. Ideally collections should be made from the field where useful information on variability and culture can be obtained, but it is a slow process. Bazaars provide access to a great range of germplasm in a short period of time, but information on the source of seed or plant material is frequently unreliable.

Most of the entries in the USDA World Collection of safflower were obtained in collection trips made in 1958 and 1964-65. At the same time collections of wild species were made, and have been used in studies of relationships of safflower species. It was possible during collection trips to become familiar with local production and utilization practices.

Wherever I have collected, local agricultural officers have been most cooperative. The USDA plant introduction officers have expedited collection and introduction procedures and have catalogued most of my collections.

PRECAUTIONS, TREATMENT, AND EVALUATION OF RICE INTRODUCTIONS FROM FOREIGN PROGRAMS

W. F. Lehman, A. J. Oakes,
J. N. Rutger, and M. W. Peterson

The rice growers in the United States are in the fortunate position of having relatively few of the important diseases and insects attacking their crop. Hoja blanca is a serious virus disease in South America and the Caribbean which once threatened to become an important disease in the United States. The brown planthopper is now a very serious insect pest in the Far East. Nematodes, because of the difficulty in elimination, could be a serious threat.

Recognizing its fortunate but vulnerable position in regard to plant pests, the rice industry has been particularly interested in seeing that no new pests are imported. The introduction of new germplasm has been regarded as necessary, but regulations concerning their importation are stringent. Introductions must be sent to plant quarantine officials in Washington, D. C., inspected, fumigated, if necessary, treated with hot water, soaked in a fungicide, and carefully inspected by the State Department of Agriculture prior to release of the U. S.-grown seed. No foreign-grown seed can be distributed.

El Centro, California, was selected as an area to grow rice introductions under quarantine because it has a long growing season, was once a rice growing area, and is about 300 miles from the nearest commercial rice field. Field plots capable of producing relatively large amounts of seed are grown and notes are taken on this field-grown seed to provide prospective users with some information on each entry.

Differences in heading date and height have been observed in introductions from various countries. Lines from Japan and Taiwan are short and early. Laos lines tend to be tall and late, but they also cover a fairly wide range for these two characters. Lines from India are tall and cover a wide range of maturities. Differences in other characters such as pigmentation, awns, and pubesence were also noted.

USING GERM PLASM IN CONSERVATION

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The primary purpose of the Soil Conservation Service's plant materials program is to develop quality plants to solve the various conservation problems. Twenty-one Plant Materials Centers throughout the U.S. conduct extensive testing programs. The California Plant Materials Center is in Lockeford, near Lodi.

The Lockeford PMC uses a five-step testing program to evaluate germ plasm from native and foreign plant collections: 1) Plant collection; 2) Initial evaluation at PMC; 3) Secondary evaluation at Field Evaluation Plantings; 4) Final testing in Field Planting; and 5) Commercial release and maintenance of germ plasm. Plants that have shown the needed characteristics for solving erosion and soil pollution problems are selected for testing. The ultimate goal is to provide quality plants to commercial suppliers for production in needed areas.

In over 40 years, 20,000 strains have been evaluated. Because of thorough testing, only 16 have been developed for use in California. These 16 are superstars in the conservation field.

'Blando' brome, Bromus mollis, is a self-perpetuating winter annual grass originally developed for rangeland improvement. It has also proven valuable for roadbanks, orchard and vineyard cover, construction sites, and other critical areas.

'Lana' woolypod vetch, Vicia dasycarpa, is a self-seeding, winter annual legume used to improve annual range production. Its use can increase forage production 65 to 116 percent. It is also valuable as a wildlife food and cover plant for dove and quail.

'Wimmera' 62 ryegrass, Lolium rigidum, is a very early maturing annual ryegrass. It is used for rapid cover on critical areas and for self-perpetuating cover for irrigated orchards and vineyards.

'Luna' pubescent wheatgrass, Agropyron trichophorum, is a New Mexico release that found a home in California. It is a cool-season, sod-forming, perennial grass used on poor rangeland at higher elevations. It is also excellent for erosion control on road slopes and year-round cover on fuel breaks.

'Zorro' annual fescue, Festuca megalura, is an aggressive, early-maturing, winter annual grass. It has excellent seedling vigor and is superior to Blando brome in establishing on infertile, shallow, low pH, or droughty soils where erosion control is critical.

Several native strains of woody plants have been developed for commercial release. They include bladderpod, sulphur-flowered buckwheat, quailbush and fourwing saltbush. These also have benefits for upland game cover on dry sites.

Through the plant materials testing program, conservation problems can be solved with superior germ plasm. Current challenges are: erosion control on problem soils; plants that can use sewage effluent; erosion control on arid areas; and low volume, drought-tolerant plants for fuel breaks.

Cooperative testing with Resource Conservation Districts and local, state and federal agencies is essential for a successful program. Through this combined effort, soil and water erosion can be reduced and we can protect our natural resource base for sustained use.

NEW BLOOD FOR OLD CROPS
GERMPLASM: A TOOL FOR PLANT BREEDING

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We define germplasm as genetic material related to crop species that comes from wild related species, non-adapted cultivars or other related forms. Germplasm has some intrinsic interest as material for genetic, physiologic, or developmental studies. Its principal usefullness, however, is as a source of new and economically useful genes or genotypes for crop plants.

Germplasm has multiple uses as a plant breeding tool. First, it is an important source of specific genes. These may be genes for disease resistance, insect resistance, male sterility or useful morphological traits. They may therefore be useful for improvement of crop species in specific ways, particularly if unobtainable in the crop itself. Sometimes foreign cytoplasms are useful for creating male sterility.

Wild species and foreign crop species that are not economically useful here may have potential for usefullness as new crops. It is difficult to change cropping patterns in a country but it is possible when the time is ripe and the need is there.

One of the important advantages in terms of the economic well-being of the country is the maintenance of the variability of a crop or of the crop complex by the constant addition of new genes and genotypes. This should parallel the maintenance of variability in the countries of origin. In the receiving countries, plant breeders, curators, botanists, geneticists and others have an obligation to preserve both the new and the old forms.

In using germplasm materials for plant breeding, it is important to realize the genes are part of chromosomes and may have undesirable neighboring genes. As much as possible, deleterious effects should be anticipated and tests devised to detect them.

PLANT-TISSUE-CELL CULTURE TECHNIQUE AS AN ADJUNCT TO PLANT BREEDING

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The use of tissue-cell culture techniques has been proposed as an important component of modern plant breeding programs. These techniques greatly facilitate the establishment of selection criteria which are necessary in the identification of specific plant genotypes with the desired performance in saline environments is well suited to the use of this technique.

Standard screening procedures for selecting salt tolerant crop plants require that large plant populations be cultivated under various salt stresses. These selected plants are then propagated, and techniques of plant breeding are applied to ensure inheritability of salt tolerant characteristics. This procedure entails prolonged, expensive operations (in growth chamber, greenhouse, and field) employing large numbers of potentially useful varieties. Imposed upon this selection process are all the other variables common to field operations.

As a way of alleviating many of the initial problems associated with standard varietal selection, it is conceivable that cell culture procedures could be used. Salt tolerant variants could be selected from large populations of individual cells cultured in media in multi-replicated sets under well defined growth environments. Thus, many different saline environments could be imposed in screening procedures that would evaluate in advance the salt tolerance of the plant cells and their chances of thriving. Recent studies have indicated successful application of the cell culture technique to selection of salt tolerant lines of tobacco and pepper plant cells.

In our tissue culture work we have worked out a "mass selection" technique for screening for salt tolerant cells, and have isolated apparently stable mutant alfalfa cells which have grown for several months at a salt level which is normally fatal to these cells. It is not clear whether the improved performance is the result of genetic changes or physiological adaptation. We have now started working on regenerating this tissue back to a whole plant, at which point we can evaluate its salt tolerance by comparing its performance with the performance of the varieties of alfalfa we grew under salt stress in a greenhouse experiment.

The ultimate objective is to regenerate the selected cells into plants which could then be supplied to plant breeders as a source of germplasm. The genetic information may be introduced into commercially important crop lines and thereby increase the exploitation of salt affected areas.

MANAGING FOREST AND RANGELAND RESOURCES
FOR GREATER PRODUCTIVITY THROUGH FERTILIZATION

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Current interest across a broad spectrum of our society indicates there are many benefits we expect to derive from publicly owned land. Hardly a day goes by that we do not hear in the news some expression of concern over reducing the amount of livestock grazing or timber harvesting from federal lands. Current studies involving several million acres of roadless areas which could go into designated wilderness would potentially reduce the harvestable timber by a substantial amount. By the same token there are plans under way which would substantially reduce the amount of acreage currently used under grazing permits by livestock owners. I have mentioned but two of the commonly referred to resources which can well be expected to yield reduced amounts of food and fiber from public lands. This seems to point to an increasing trend wherein greater productivity will have to be derived from the privately held resource base. Currently even this pursuit is being challenged by a number of environmentally concerned interest groups because of the additional restrictions implemented which affect resource management.

As one begins to assess the various inputs that can be implemented in terms of increasing the productivity from forest and rangeland resources, fertilization is among those having considerable potential. Grazing studies have indicated increases in pounds of beef produced ranging from 50 to well over 100 percent as a result of nitrogen fertilization. Additions of phosphorus, sulfur and occasionally other nutrients have usually resulted in less dramatic increases unless their application was in conjunction with the seeding of legumes which provided more adequate supplies of nitrogen. Substantial increases in the volume of wood produced has been reported by numerous researches. It must be said in the case of perennial crops such as trees, however, that other management practices such as thinning and age of species when fertilizer is applied influence greatly the rate of growth.

The question immediately arises as to what, where and when would fertilizer response be the greatest. Since nitrogen is the nutrient most limiting plant growth it desires the greatest attention. Forage production from rangeland is perhaps most economically increased if legumes can be seeded to provide additional nitrogen. Phosphorus, sulfur and in some situations lime may be necessary for establishment and maintenance of the most beneficial production. On vast acreages where viable stands of legumes are impossible to maintain, nitrogen will need to be supplied by fertilizer sources. Although larger responses usually occur on sites of medium inherent fertility having the more desirable plant species where 10 to 40 inches annual precipitation is received, ranchers need to use trial and error experience to develop more detailed information for their individual location. This would of necessity involve the evaluation of phosphorus and/or sulfur response when added to nitrogen. Soil tests can be fairly reliable in predicting phosphorus needs of range soils. Analysis of plant tissue during the active growth stages can be used as a guide to indicate the most deficient nutrient. Economics will usually favor an application rate of 40 to 80 lbs N, and if necessary 15 to 30 lbs P_2O_5 and 10 to 20 lbs S/A every other year. If legumes make up a viable portion of the productive plant species 20 to 40 lbs P_2O_5 and/or 15 to 25 lbs S/A applied every other year will maintain economical production levels. Little, if any nitrogen need be applied to legumes except for seedling establishment.

Guidelines for the fertilization of forest lands are a much more complex subject. Perhaps the most perplexing question is when in the 50 to 75 year or more life span of trees will the response to fertilization be the most beneficial. Considerable experimentation has involved the preharvest period because it represents a sufficiently shorter waiting period for realization of return on investment and interest costs from the increased yields. The most significant growth response is from nitrogen with only slightly greater response from nitrogen plus phosphorus, potassium, sulfur and/or magnesium. The major portion of this response occurs the first four years after application and may continue for up to ten years. Soil tests and foliage analyses have been somewhat helpful, however correlation studies are of necessity long term and must be interpreted within the context of soil, climate, vegetative species present and other site specific characteristics. Considerably more research will be necessary to gain insight regarding the most advantageous areas to realize the greatest potential from forest fertilization.

SOIL SURVEYS AND LAND USE PLANNING

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A soil survey is the <u>foundation</u> of wise land use planning. Farmers and ranchers, foresters, city planning boards, urban developers, highway engineers, recreation developers, scientists, and technicians use soil survey information.

The basic purposes of soil survey are: (1) to determine the important characteristics of soils, (2) to classify the soils and name them according to a nation-wide system, (3) to interpret the soils for various uses according to their capabilities, (4) to show the distribution of soils on maps, and (5) to publish the results as soil survey reports including maps, the basic soil descriptions and the basic interpretations.

Purposes and Uses of Soil Surveys

The primary objective of soil surveys has been and is to study, classify, describe and map soils so that predictions can be made about their behavior for various uses and, their response to defined management systems.

Soil surveys are used extensively as one of the important bases for planning farms, ranches, forests, towns, and larger regions such as counties and states.

In addition to farm and ranch use, in recent years soil survey interpretations are reflecting more and more the needs of nonfarm land use planning.

Soil surveys can be done to meet the needs of the intended users. Although soil surveys can be made to satisfy a single purpose, this is rarely done. Most commonly they are done for areas sufficiently large to have more than one kind of important land use and several or more users with varied interests and needs.

Soil survey maps and interpretations are fundamental and versatile tools for helping individuals and communities solve many kinds of immediate and future problems in the use of land.

Soils should not be used for farming, industrial sites, recreational sites, forest production or other purposes unless they are suited for that purpose or can be made so economically.

A COUNTY NATURAL RESOURCES PROGRAM

Eldred S. Bliss
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Fresno County, like most areas blessed with abundant and varied natural resources, faces the traditional problems of their development, conservation and wise use. "Local control," one of the slogans of our time, is widely desired but also widely known for its pitfalls. One approach to this problem in Fresno County was the development of the Natural Resources Coordinator concept. While the function is expected to review evolving State and National legislative proposals affecting natural resources and to assist in developing needed local legislation, a more important aspect is its relation to the many agencies, State, Federal, and local that carry on programs affecting use or conservation of natural resources. These programs are so numerous, varied, and complex and carried out by such a maze of often unknown agencies that local decisionmakers are often trapped into decisions that are detrimental to their own interests. Staff members of many Federal and State agencies have little understanding of the concerns or fears of local people regarding the programs they administer, nor do they usually understand local conditions and variables that affect their programs at that level.

The Natural Resources Coordinator attempts to bridge this gap by communicating to decisionmakers what the programs are designed to do, how they appear to relate to Fresno

County conerns, and what alternative actions seem appropriate at the local level. To Federal, State and local staff members involved, the Natural Resources Coordinator interprets local conditions affecting the programs and the concerns, misunderstandings, and prejudices of local people.

RATING AGRICULTURAL LAND CAPABILITY: A COMPARISON OF THREE SYSTEMS

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As the human population expands, all uses of land and soil become more competitive. Increasing pressure is being placed on prime agricultural land from urban growth and public facilities such as highways and airports. At the same time, the basic demand for the production of food is increasing. The present land market system is not adequate to assure protection and rational utilization of our productive land resources for future, as well as for present, use. Sound land-use planning by local, state, and federal agencies, which includes the identification of the most productive agricultural land, is essential in supplementing the land market process. These acres of "prime" agricultural land should be preserved to meet the long-range demand for food.

In the California State Legislature there have been several bills proposed for the long-range preservation and conservation of prime agricultural land. The criteria used in these bills for defining prime agricultural land is based mainly on one or a combination of the following three agricultural land classification systems: (1) the Storie Index Rating System, (2) the USDA Capability Classification System, and (3) the USDA Land Inventory and Monitoring System (LIM).

This paper reports on quantitative comparisons of these three different agricultural land classification systems using soils information from test counties in California. It demonstrates how different soil series are classified by the three systems and how many acres of prime and non-prime agricultural land are included in each system.

A comparison of these three systems give us an idea of their efficiency in defining and identifying land that should remain in agricultural preserve. From a good land use classification system and available soils data, we can then determine how much prime agricultural land will be available for future use.

LAND RESTORATION ON THE TRANS ALASKA PIPELINE

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The Trans Alaska pipe carries oil from Prudhoe Bay to Valdez. There are 12 permanent pump stations along the pipeline. Twenty construction camps were also built which will be removed.

Two basic construction types were employed. One is the conventional, below ground method. The other is the new, above ground construction. The later method is used where the subsoil contains ice.

Land restoration starts with grading. The surface is smoothed and scarified before seeding. Fertilizer is applied to all seeded areas. For seeding, gravity flow, blower and hydroseeders were used. Aircraft was also used. Seed mixtures and rates varied according to conditions at the site. Seed is covered with a chain or harrow.

Critical sites are mulched with straw. Tooth roller anchors the straw to the ground.

Seeding was timed for two periods each year. One is in the spring-summer and one in the late fall, until snow prevents it.

Construction areas, after restoration, change rapidly to grassland. Two to three months after construction is completed at a site, the grass is tall.

Because of continuous light, plants grow fast during the short growing season. They use up nutrients rapidly from the soil. Soils are frozen most of the time and cold even during the growing season, therefore, fertility is low. Response to applied nutrients under these conditions is strong.

Livestock, wildlife grazes on the restored land. This is the best feed supply many of these animals ever had.

In the fall the annual grass forms a thick mat over the land and protects it from erosion. In the next growing season the perennials grow through the mat and colonize the land.

Natural return of vegetation to a bare site is very slow there. Grasses and other invading plants are few. After 20 years a pipeline route still has no trees or shrubs.

In the arctic the northern most planting was established in 1976 at latitude 69 1/2 north. In this area day light is continuous from May 10 to August 1st. Perennial grasses, such as redtop produces seed.

Thermal erosion results at sites where vegetation was removed. The underground ice thaws and the ground caves in. The establishment of vegetation reduces thermal erosion not only beautifies the landscape.

Soils are very shallow and often underlain by ice lenses close to the surface. This ice in some years gets thicker, in other years melts down.

Trees have very shallow root systems, not more than 10 to 15 in.

Alaska is a place where one still can see a grizzly bear.

RESOURCE MANAGEMENT IN AGRICULTURE
SOME REMOTE SENSING APPLICATIONS IN LAND RESOURCE MANAGEMENT

Charles B. Goudey
USDA, US Forest Service, Nevada City

From satellite imagery to large scale aerial photography, examples are shown how various kinds of imagery have been applied to some resource inventories and land use assessments. Applications of large scale (greater than 1:10,000) color and color IR films for vegetative interpretations are compared. Procedures for acquiring existing remotely sensed data, and the costs and considerations of procuring new aerial photography are also presented.

NEW VARIETY TURFGRASS RESEARCH AT THE UNIVERSITY OF CALIFORNIA SOUTH COAST FIELD STATION

Stanley Spaulding, Staff Research Associate
Dept. of Plant Sciences, University of California, Riverside

The responsibility for breeding, developing, and evaluating new turfgrasses on the South Coast Field Station is divided. Dr. Victor B. Youngner, Professor of Agronomy, Riverside, is the project leader. As a plant geneticist he directs the breeding and development of improved types of turf plants.

Dr. Victor A. Gibeault, Cooperative Extension, Environmental Horticulturist, is concerned with the evaluation of other breeders' creations, and with cultural management studies.

New turfgrasses are developed for specific uses, better performance, and better appearance. For example, 'Santa Ana' bermudagrass was introduced for better color, winter and summer, than in other cultivars. Unlike others it is not discolored by smog. Although 'Santa Ana' has characteristics for the best all year athletic turf it is used extensively for residential lawns.

However, one turfgrass is not suitable for all environments, purposes, and tastes. For this reason, bermudagrass breeding is continuous at the field station. Cultivars better than 'Santa Ana' are sought. People of the inland valleys want bermudagrasses that combine well with cool season grasses. Evergreen turf is made in this way, because there is no bermudagrass on the horizon that stays green in temperatures prevailing below 40° F.

Bermudagrass vs Zoysiagrass

Lawn owners complain that hybrid bermudagrasses grow too much. Too much time and money is required to dethatch and groom bermudagrss through the long warm season. Similar in appearance and adaptability is Zoysiagrass, except more than a year is required to make a fully covered and dense turf.

Years of breeding and selection in the University went by before significant improvements were made. Today, seedlings at the station are seen with improved vigor and winter color with a variety of textures and growth habits to choose from.

There may be some new Zoysiagrasses suitable for ground cover. Low, dense turf free of noxious flowers and seeds is seen in breeding progeny. In contrast, unmowed bermudagrasses produce a profusion of brown flowers and seeds for months on end. This condition can't be tolerated on parkway slopes where mowing is impracticable.

Dichondra Improvement is Slow

For many years much study has been devoted towards the creation of an improved dichondra turf. U.C.R. 1 out of University research is in growers' fields. Introduction will be by decision of the dichondra seed industry, that has contributed financially for dichondra research.

Substantial progress is being made. Fungal disease and nematode resistant taxons are appearing out of breeding work. However, flea beetle and extreme cold temperature tolerance has not been seen as yet. For this purpose dichondra collections, world-wide, are being evaluated for future breeding.

Other Warm Season Grasses

'Fu-Turf' and 'Adelaide' cultivars of Paspalum vaginatum are being observed for turf quality under different nitrogen fertilizer rates and two mowing heights.

These new Paspalums are commercial introductions produced for sod and stolons in the Coachella Valley. Heat tolerance is indicated and Utah State University reports high soil salinity tolerance. Earlier work at this station showed winter color equal to the best of other warm season turfgrasses. Because 'Fu-Turf' and 'Adelaide' are being planted extensively, only a few more years are needed to see if they are here to stay.

Turf Forming Tall Fescuegrass

In the last stages of development at the station are Tall fescuegrasses with a finer texture than those in current use. The new ones possess a habit of dense tillering. This is a result of many years of inbreeding and selection for an extensive rhizome system.

Before seed is available for making a lawn, the breeder's selections must be tested and found to be copious seed producers by commercial seedsmen.

New Fine Textured Perennial Ryegrasses

Perennial ryegrass is greatly improved. Texture has been changed from coarse to fine. Growth habit is lower and denser, and color is darker. No one introduction is superior, to date, in all categories. Evaluations are not conclusive in 2½ years of observation. The following have received high ratings: Blazer, Citation, Derby, Fiesta, Loretta, Pennfine, and Regal.

Many New Kentucky Bluegrasses

Kentucky bluegrass receives much attention from breeders, because it is the universal favorite lawn grass. Thirty-three new bluegrasses are under study at the station.

After 2½ years a great difference between the cultivars is a tolerance of high temperatures and associated fungal diseases, the most damaging of which is "summer blight". The causal organism is _Fusarium roseum_.

Differences are seen from time to time when "rust", "leaf spot", and "melting out" diseases appear. As with "summer blight" the above diseases affect turf quality, but generally, only for a few days to a couple of weeks. _Fusarium_ kills roots and large areas of turf. The voids do not fill in until the next spring, and weeds invade during fall and winter.

At the end of summer several bluegrasses in the study have unsatisfactory cover. Adelphi and Parade plots are totally covered and dense. Other acceptable cultivars are A34, Baron, Enmundi, Geronimo, IS28, Rugby, Scenic, Vantage, Victa, and Windsor.

Studies will continue before results are conclusive.

ROUNDUP® HERBICIDE REGISTRATION FOR TURF

John Houghton, Monsanto Company
Fresno

Monsanto's Roundup® herbicide received commercial label clearance for turfgrass application August 9, 1977. This addition to the existing commercial label allows the application of Roundup® for the purposes of establishing or renovating turfgrass areas such as commerical turfgrass production fields, golf courses, schools, parks, recreation facilities, landscapes, and domestic areas if applied by professional applicators.

The characteristics of Roundup® which make it suitable for turfgrass establishment and renovation are its (1) water solubility, (2) negligible volatility, (3) surfactant content for postemergence application to target plant species, (4) broad spectrum control, (5) no soil herbicidal activity, and (6) translocation into underground root systems of perennial plants resulting in their complete control. Roundup® contains 3 lbs/gal acid equivalent (a.e.) of glyphosate or 4 lbs/gal active ingredient (a.i.) of the isopropylamine salt of glyphosate. The commercial formulation of Roundup® contains a surfactant.

The application rates of Roundup® to be used in turfgrass establishment or renovation are those rates listed on the label for the particular weedy species to be controlled. For example, for bermudagrass control Roundup® should be applied at the 5 quart/acre rate in 20-60 gallons of water per acre when conventional boom equipment is used. If handheld and high-volume equipment is used, 4 quarts of Roundup® per 100 gallons of water should be mixed and the application made on a spray-to-wet basis.

Factors affecting the activity of Roundup® are (1) rate responses depending on the target species, (2) proper volume of water carrier, (3) existing canopy effect, (4) shade, (5) rainfall or sprinkler irrigation timing, (6) vigor of growth of the treated plants, (7) dust and dirt on the leaves of treated plants, and (8) mowing or clipping operations relative to the time of application.

The symptoms of Roundup® activity are a gradual wilting and yellowing of the treated plant, which advances to complete browning and deterioration of the plant tissues. Since Roundup® has no soil herbicidal activity, turfgrass establishment may proceed immediately after insuring that no regrowth of the undesired species has occurred in the treated area. Regrowth may occur from escaped underground plant parts. As Roundup® does not provide residual weed control, a label-approved herbicide program for subsequent weed control should be followed.

Extreme care must be exercised to avoid bringing the Roundup® spray into contact with the foliage of desirable turfgrasses, trees, shrubs, or other desirable vegetation, since severe damage or destruction of these plants may result.

NEW DEVELOPMENTS IN ARBORICULTURE

Austin B. Carroll
Citrus Heights

I know from the title of this paper many are expecting to hear a first in tree care. But we must remember arboriculture is not a new art or science. In his book, Enquiry in Plants, written about 300 B.C., the greek scientist Theophrastus described plastering wounds with mud to prevent trees from decaying.

So it appears that since the beginning of time many investigators have written on the subject of trees and tree care. What's new can only be new people, techniques, chemicals, and equipment to answer age old questions.

After more than forty years working with trees and tree problems I have found trees and their problems have not changed much in my lifetime; and I have about come to the conclusion that most trees grow in spite of us rather than because of us.

Man's misuse, abuse and encroachment on to native stands of trees has developed problems that are referred to as tree problems and because of the economics involved new people, techniques, chemical and equipment evolved.

As you are aware only time can evaluate the success or failure of much of the new people, techniques, chemicals, and equipment introduced to the industry the past few years.

New People

The most important of the new in the industry are the new young people that come to us from our universities, and colleges who have been inspired by some very great instructors such as Dr. Howard C. Brown, Dr. Richard W. Harris, Dr. L. C. Chadwick and many more. These young people, men and women, are our think tank of the industry which will keep new developments in the field of arboriculture coming.

The author is not aware of all of the new techniques, chemicals or equipment but I will mention a few in hopes of stimulating you to think of others.

New Techniques

Implant or injection of insecticides, fungicides, antibiotics and fertilizers to replace spraying.

Aerating under paving by use of porous concrete and Turf Stone to replace trenching and tile system.

Application of growth retardant to replace pruning.

Controlling root growth with plastic planters and barriers.

New Chemicals

Systemics - Compounds which, applied to soil, foliage or injected, are absorbed by the plant or translocated within it.

Trade names of a few:

Cygon®, Meta Systox®, Orthene®- which are insecticides.

Benlate®- which is a fungicide.

Maintain®, CF-125®, SloGrow®- which are growth retardant.

This by no means is all of the systemic chemicals. To simplify information, trade names of products have been used. No endorsement of named products is intended, nor is criticism implied of similar products which are not mentioned.

New Equipment

The light weight chain saw, with a skilled trimmer, can almost replace the handsaw in large trees.

The aerial lifts - on street trees - reduces man or crew hours.

Pneumatic and hydraulic - pruning tools - usually used with lifts.

Mechanical tree movers - to replace boxing and/or balling.

Brush chippers - volume reduction of trimmings.

Closed system sprayers - operator is not exposed to chemical while mixing.

Stump grinders - no hand digging, less area disturbed, no stump to dispose of.

This also is only a small part of the new equipment and to some younger people in this group it might not sound like new equipment.

New Diagnostic Equipment

Gas Analyzers

Dr. Spencer H. Davis, Jr. of Rutgers University, in his studies of the effect of natural gas on trees and other vegetation, has found that the extreme low oxygen concentration in the soil to be the most important cause of death of trees. His studies were aided with the use of a Gas Analyzer to measure the carbon dioxide and oxygen. This equipment will take special skills to use but its possibilities certainly are fascinating for diagnostic use.

Dr. A. L. Shigo of the USDA Forest Service, Northeastern Forest Experiment Station, Durham, New Hampshire, has made an extensive study of the decay process in living trees, and through this has developed a meter to determine the internal condition of the tree and of course it is named the Shigometer.

To detect decay in trees a 3/32 inch hole is drilled into the tree. A special probe is inserted into the hole, and the electrical resistance of the wood at the probe tip is recorded on the meter. When the probe tip is moved from sound to decayed wood, there is an abrupt decrease in resistance. Thus you can imagine the value of such a tool in skilled hands.

My time will not allow me to go into detail on this subject, but I do hope I have given you something to think about.

WHAT'S NEW IN FIRE RETARDANT PLANT MATERIAL

Richard G. Maire
University of California, Los Angeles

There is really not too much new work being done in the testing of plants for fire retardant characteristics. Most of the work done on fire retardant plants dates back to the Bel Air fire of 1961. Of course, work had been done prior to that date because fires have been with us in the hills of California as far back as records have been maintained.

A more recent report has been done by Nord and Green. It contains valuable information on native and landscape plant material use for reducing fire hazard and I will cover their findings in this report.

First and foremost, I feel it is essential to stress the fact that: THERE IS NO SUCH THING AS A PLANT THAT WILL NOT BURN. THE TERM "FIRE RESISTANT" HAS BEEN USED AND MAY BE MISLEADING. ALL PLANTS WILL BURN, IF THERE IS ENOUGH HEAT AND IF OTHER CONDITIONS ARE RIGHT.

Before getting into plant materials, let us review the Guidelines to Reduce Fire Hazard, as published by Alameda County Cooperative Extension.

1. Increase effectiveness of plantings by installing a high pressure sprinkler system. It takes time for water to get through the soil into the roots and up the leaves. So, keep leaves turgid with an on-going irrigation program.

2. Keep the land bare around all structures or plant lawns, succulent ground covers, or other low-growing plants. Many California native plants may not be acceptable because they do not tolerate summer irrigation. Other plants should be watered regularly, especially during times of low humidity and easterly winds (September, October, November and December).

3. Keep the landscape and exposed areas under and around buildings clean. Remove accumulated dry, dead litter under trees and shrubs. However, leaving a thin mat of plant litter will reduce the dust nuisance and provide some control of sheet erosion. It should not be enough to carry much of a fire. Do not permit storage near a building of any easy-to-light material which would carry fire to the building.

4. Remove dead and dried portions of ground covers, succulents, and trees. We saw where fire crept through dead areas of iceplants.

5. Do not allow a continuous tree or brush growth next to buildings. Besides the fire hazard, litter accumulates in gutters. Trees and shrubs should be planted at least six feet away from a building. This allows for proper air circulation, and shading of the walls during the warm months. Building maintenance and structural pest control is easier. Plants are able to grow in a natural form and pest control problems are reduced.

6. Leave a wide space between clumps of trees and shrubs to help reduce the spread of fire. This would be most important at the beginning of a fire and when winds are light.

7. Maintain a distinct break between low-growing plants and high-growing trees. This prevents a ground fire from reaching tree tops, an important advantage.

8. Plant and encourage "heat shields" or "screens". Thick, well-watered hedges planted at least 20 feet from a building were effective in preventing fire from reaching buildings in the Oakland hills fire.

9. Use asphalt shingles or a roof of asphalt and rock. These are less flammable than wood shake and shingle roofs.

These grasses are used for temporary protection:

1. Bromus mollis (soft chess). Good annual native grass that reseeds itself. It gives quick cover and grows 6 to 12 inches high, depending on available moisture. It needs moisture to germinate but will survive on natural rainfall, once established. Plant at the rate of 10 pounds per acre.

2. Hordeum vulgare (barley). Annual grass, useful for temporary plantings prior to permanent landscaping. It will reseed unless seed heads are cut off. It germinates readily and gives a rapid cover if irrigated. Plant at the rate of 30 to 40 pounds per acres.

3. Lolium multiflorum (annual ryegrass). Most commonly planted in burned areas. A percentage of the seed will be perennial ryegrass, which will carry over in following years and be difficult to dispose of under irrigated conditions. Plant 20 to 40 pounds per acre for home use (½ to 1 pound per 1000 square feet). Airplane seeding can be performed at 8 to 10 pounds per acre.

Grass species recommended for fuelbreak sites in California (adapted from Green and others 1963, and Bentley 1967):

Hardinggrass
Smilograss
Veldtgrass
Pubescent wheatgrass
Intermediate wheatgrass
Tall fescue
Sherman big bluegrass
Orchardgrass
Crested wheatgrass
Blando brome (annual)

The following ground covers, shrubs, and trees represent only a few of the many excellent plants available for landscaping irrigated hillsides for fire protection. Always keep in mind the need for reducing fuel volume to a minimum while achieving the desired protective and esthetic effects.

GROUND COVERS

Iceplant types:
- Fig marigold
- Red spike iceplant
- White iceplant
- Rose iceplant
- Yellow iceplant
- Croceum iceplant
- Bush type iceplant
- Purple iceplant
- Trailing iceplant
- Redondo creeper

Baccharis pilularis prostratus (dwarf coyote bush)
Hedera canariensis (Algerian ivy)
Helianthemum nummularium (sunrose)
Osteospermum fruiticosum (African creeping daisy)
Rosmarinus officinalis prostrata (creeping rosemary)

SHRUBS

Ceanothus griseus horizontalis (Carmel creeper)
Cistus vellosus (rockrose)
Heteromeles arbutifolia (toyon)
Nerium oleander (oleander) (ALL PARTS OF THIS PLANT ARE POISONOUS)
Rhamnus alaternaus (Italian buckthorn)
Rhus integrifolia (lemonade berry)

TREES

Ceratonia siliqua (carob)
Eucalyptus species
Schinus molle (California pepper)
Schinus terebinthifolia (Brazilian pepper)
Umbellularia californica (California laurel)
Washingtonia species (fan palms)

The following low-growing shrub species are rated "Good Performance" when used for plantings to reduce fire hazards in southern California brushland clearings. Compiled by Nord and Green. (Native source listed).

Salvia sonomensis, Creeping or Sonoma sage, California
Santolina Chamae cyparissus, Gray santolina or lavendercotton, Mediterranean region
Santolina virens, Green santolina or lavendercotton, Mediterranean region

The following are rated "Fair Performance":

Artemisia caucasica, Caucasian artemisia, USSR
Atriplex cuneata, Castlevalley saltbush, central Utah
Atriplex gardneri, Gardner's saltbush, Utah
Atriplex mulleri, Muller's saltbush, Australia
Atriplex semibaccata, Austrailian saltbush, Australia (Nat. U.S.)
Baccharis pilularis, Prostrate or dwarf baccharis, California
Atriplex falcata, "Falcata" saltbush, Great Basin region
Atriplex inflata, Flat-topped saltbush, Australia
Atriplex nuttallii, Nuttall's saltbush, Great Basin region
Ceanothus griseus var. horizontalis, Carmel creeper ceanothus, California
Ceanothus prostratus, Prostrate ceanotinus or squaw-carpet, Sierra-Nevada, Cascade
Galenia pubescens, Green glaneia, South Africa (Nat. Australia)
Myoporum parvifolium, Myoporum "Horshum" cultivar, Australia

Cistus crispus, Descanso rockrose from the Mediterranean region, is a semiprostrate shrub rated "Good Performance" when used to reduce fire hazards. The following are rated as "Fair Performance":

Arctostaphylos myrtifolia, Ione manzanita, California
Arctostaphylos confertifolia, Shadscale saltbush, Western United States
Ceanothus masonii, Mason's ceanothus, California

The following publications are available from the University of California Cooperative Extension Service:

2398 - Clear Away Brush---Cut Your Fire Hazard
2399 - Fireproof Your Forest Home
2400 - Guarding Your Home Against Wildfire
2401 - Landscape For Fire Protection
2402 - Brush Management---Use of Prescribed Fire
2403 - Overhead Sprinklers and Water Supplies
2142 - Fire! It Can be Controlled

"Green Belts For Brush Fire Protection and Soil Erosion Control in Hillside Residential Areas" can be ordered from the California Arboretum Foundation, 301 North Baldwin Avenue, Arcadia, 91006. Please send $1 with the order for each booklet.

DUTCH ELM DISEASE IN CALIFORNIA

Art McCain
University of California, Berkeley

Dutch elm disease is so-called because much of the early work was done in Holland. The disease was first discovered in France in 1918 and in neighboring countries within a few years. It is generally believed that the disease had its origin in Asia where it occurs in resistant but not immune species and was brought to Europe where it spread to susceptible elms. The disease was found in England in 1927 and introduced into the U.S. in 1930 on elm logs imported for veneers. The disease has spread steadily across the states, generally preceded a few years by elm bark beetles. It was first discovered in California in 1975 in Sonoma and Napa Counties. In 1976 it was discovered in Marin and Santa Clara Counties and in 1977 in Solano and San Mateo Counties. When diseased elms were cut down in California, dark rings in old wood indicative of infection were found and the fungus recovered from some of these rings. The infected rings were dated and it is apparent that the disease has been present for 15 years in Sonoma County, 7 years in Napa, Santa Clara, San Mateo, and Solano Counties and for 2 years in Marin County. It is the opinion of some plant pathologists that the disease will continue to spread to other parts of California in spite of the California Department of Food and Agriculture program to eradicate the disease.

The elm disease is caused by a fungus called *Ceratocystis ulmi*. It is capable of infecting native and exotic elms. *Zelkova* sp. and *Planera* sp. have been infected when artificially inoculated with the fungus but the disease does not occur naturally. The principal carrier of the fungus is the smaller European elm bark beetle, *Scolytus multistriatus*. This beetle has been present in California since 1953. It is also carried by the native elm bark beetle, *Hylurgopinus rufipes*, which is not known to occur in California. Control of elm disease revolves around the control of the carrier. When the beetles emerge in the spring they fly to nearby living elms and feed often in the crotches of small 1- or 2-year-old twigs. If a beetle is carrying spores of the fungus, the twig may become infected.

The first visible evidence of the disease is the wilting and yellowing or drying of foliage on one or more branches of the tree. Leaves on affected branches usually fall and the branch dies. If the tree is infected in early summer, the disease may spread to the entire tree and death will follow in the same season. Brown streaks develop in the sapwood of the infected branches. In cross section the discoloration appears as a brown ring in the springwood or current season growth. The disease can usually be diagnosed on the basis of the discoloration in the wood and confirmed by laboratory cultures.

No single method has been successful in controlling DED, as evidenced by the destructiveness of the disease. Primary emphasis in control is upon prevention. Sanitation aimed at eliminating breeding sites of the beetle is the backbone of all control programs. Spraying elms with an insecticide will not prevent DED but the rate of spread can be reduced by killing the beetles. Methoxychlor is the only insecticide currently registered for control of elm bark beetles.

Trunk injections of the fungicide, methyl 2-benzimidazole carbamate phosphate (Arbora1®, Lignasan®) have provided protection against infection. Recently a related fungicide, thiabendazole hypophosphite (Arbotect®) has received registration, as an aid in the control of the disease. Both fungicides are diluted with water before use. Methyl 2-benzimidazole carbamate phosphate is effective only during the season that it is injected since the chemical is mobile and accumulates in the leaves. Thiabendazole does not move readily into the leaves and therefore lasts longer in the tree. It also moves into new twigs not present at the time of injection.

IRRIGATION MANAGEMENT SERVICES (IMS)

Gordon Lyford
USBR, Sacramento

The Bureau of Reclamation has a program which provides the tools and concepts for improving irrigation efficiencies and project operation efficiencies throughout the West. This program, using the principle of irrigation scheduling, is called the Irrigation Management Service Program, or IMS. It is a computer program originally developed by Dr. Marvin Jensen of ARS at the Snake River Research Station in Kimberly, Idaho, in the middle 1960's. The Bureau has since 1968 adopted the work of Dr. Jensen and continually modified the programs to fit the Bureau's specific needs. The recent work of the Bureau has been focused on modifying the computer programs so that they can be operated on the new generation of mini computers.

The principal elements of the computer program include potential evapotranspiration rates (ETP), crop evapotranspiration rates (ET), soil moisture depletions, allowable depletions, irrigation efficiencies, and long-term average ETP rates. ETP's are calculated daily with measurements of solar radiation, 24-hour wind movement, air temperatures, and vapor pressure. These parameters are used in the Penman combination equation to calculate the daily atmospheric demand for moisture which is equivalent to the ET of well-fertilized and properly irrigated alfalfa with approximately 40 cm of top growth. The ETP is only a potential and specific crops will have ET rates less than or equal to the ETP depending on the resistance to ET in the specific crop and soil environment.

The calculated ETP is used to calculate the ET of specific crops using crop curves. A crop curve is a smooth best fit polynomial curve that connects points obtained from the division of ET by ETP for each day over the entire growing season. Using these crop curves the crop coefficient value K is obtained from plots made against the percent of summation of Jensen-Haise ETP values. With this procedure the accumulated effects of solar radiation times temperature controls the stage of growth of the crop and the crop coefficient values (K). All of the above description is for determining the ET of any specific crop, and the relation is simply expressed as ET = ETP x K.

Once the daily ET rate of any crop is known then to time an irrigation the value for the allowable depletion is required. The allowable depletion is how dry the root zone is allowed to become before an irrigation is applied. This depends on crop, stage of growth, soil, water quality, and climate. Values for allowable depletion can be determined from charts listed in F.A.O. Irrigation and Drainage Paper No. 24, 1977 Edition, and from papers written by Professor John L. Merrian describing MAD which is synonymous with allowable depletion. Another source is Consumptive Use of Water and Irrigation Water Requirements, ASCE. During the irrigation season soil moisture depletions should be made about weekly to determine the effectiveness of recent irrigations and to update calculated soil moisture deficiencies if necessary. Therefore, the allowable depletion minus the measured or calculated depletion equals the soil moisture remaining to use before the next irrigation. The date of the next irrigation should be on the day when the soil moisture depletion is projected with an average ETP curve times K to equal the allowable depletion. The amount of water to apply is equal to the soil moisture depletion divided by the irrigation efficiency.

The above description is an overview of the technique used to schedule on-farm irrigations. In addition to doing the above the computer program stores data from each field for use later in the year. The computer is essentially a bookkeeping tool that enables irrigation experts to do the scheduling efficiently. The usefulness and benefits of computerized irrigation scheduling is now well-established, and this is being demonstrated by the Bureau and many reputable agricultural consultant companies on more than one million acres each year.

The Bureau is now increasing its emphasis on developing system scheduling. System scheduling is an additional set of sophisticated computer programs that extends information from individual irrigated fields within an irrigation district to the entire distribution system. The advantage of this procedure is that daily quantification of the district's water supply and demand can be maintained. It will also help simplify the clerical operations of most districts.

System scheduling is essentially an information management system that can save clerical time and can provide more accurate and timely data to the watermaster.

A more complete description of IMS including example printouts that a farmer would receive and example system scheduling printouts can be obtained from the Bureau.

WATER AND ENERGY CONSERVATION IN PRESSURIZED IRRIGATION SYSTEMS

Elias Fereres
Coop. Extension Service
University of California, Davis

The use of pressurized irrigation systems (sprinkler and drip) is frequently advocated as a means to conserve water in irrigation. It is often assumed that the efficiency of application in sprinkler or drip irrigation largely exceeds that of the more traditional surface methods; as a result of this, large water savings are predicted if farmers would convert their surface irrigation systems to sprinkler and/or drip. However, in many instances surface irrigation efficiency compares well with that of sprinkler or drip, thus conversion may not always be justified. In addition, an examination of the irrigation efficiency at the basin level, may indicate that in some cases where the losses from surface irrigation are being reused, actual water savings by conversion to more efficient methods of irrigation may be limited. Sprinkler and drip are capital and energy intensive methods as compared to surface systems. Nevertheless, their use is fully justified under many topographic, soil and crop situations. It is recommended that a detailed economical and technical analysis be carried out to assess the additional energy expenditures and the potential water savings when present surface irrigation systems are to be converted to sprinkler or to drip irrigation.

ON-FARM WATER MANAGEMENT FOR MINIMAL LEACHING

Jan van Schilfgaarde
US Salinity Lab, Riverside

In 1973, USSL began actively advocating the desirability of increasing water use efficiency in irrigation, based on a reevaluation of existing data on plant tolerance and soil and water chemistry and on soil physical principles, combined with the realization that there is a worldwide need to conserve -- i.e., use effectively -- our limited natural resources, particularly water and fossil energy. The term minimal leaching has since been associated with this viewpoint.

With careful irrigation management, total water applications can be reduced below those frequently encountered and below those calculated on the basis of conventional leaching requirements without affecting crop yields. The consequences, in terms of water and energy savings and changes in water quality of the irrigation return flow, depend on the circumstances. Some typical situations will be described to illustrate the possible gains as well as limitations.

Practical application of the principles outlined may require adaptation of existing irrigation systems or development of new ones, as well as changes in the water distribution system. For example, laser plane grading may make possible substantial increases in irrigation uniformity for deadlevel flood systems, and low pressure bubblers can be used to obtain a higher level of uniformity for tree crops at a lower energy cost than drip irrigation systems. However, the former requires relatively large and constant streams (heads) of water, while the latter requires continuous water delivery at low hydraulic head. Thus the demands for each on the delivery systems are drastically different.

PLANNING FOR CONTROL OF NONPOINT SOURCES OF WATER POLLUTION IN CALIFORNIA

Robert S. Miller and Robert H. Lewis
U. S. Soil Conservation Service and
State Water Resources Control Board, respectively

Introduction

During the mid-1970's California's State Water Resources Control Board and the nine Regional Water Quality Control Boards completed basin water quality control plans statewide that set water quality objectives and described necessary actions for municipalities and industries to protect waters of the State. While point source controls are covered adequately in the basin plans, additional planning effort was recognized as a prerequisite for adopting controls on nonpoint waste sources derived from silvicultural, agricultural, and construction activities.

208 Planning

As a follow-on to basin planning, and in response to the Federal Water Pollution Control Act of 1972, areawide wastewater management (208) planning is being conducted in so called designated and nondesignated areas of the State. This activity, which is being led by the State and Regional Boards along with regional planning organizations, stresses solutions for nonpoint sources of pollution and programs to implement those solutions. Major planning areas include logging, road construction, mining, hazardous wastes, and agriculturally related activities. A number of federal, state, and local agencies are participating in the program which is being advised by regional policy and technical committees. Source control or nonstructural solutions, as opposed to "end of the pipe" treatment, is receiving primary focus through the State. These solutions are thought of as best management practices (BMPs) which are those control activities that minimize the deposition of pollutants in surface or groundwaters but that are socially and economically acceptable and implementable.

Evolution of Controls for Agricultural Wastes

A somewhat erratic course has been followed for control of agricultural related wastes since passage of the Federal Water Pollution Control Act (P. L. 92-500). EPA regulations pursuant to the Act called for issuance of discharge (NPDES) permits to all point source dischargers, including irrigated farming operations of more than 3,000 acres. In response to those regulations, and after recommendations from its Agricultural Water Quality Advisory Committee, the State issued permits to irrigators that called for submission of self-monitoring data but that did not require effluent limitations.

Following a court decision in favor of the Natural Resources Defense Council, EPA promulgated regulations that included all point sources within the NPDES permit program irrespective of acreage size, but which gave California the options of issuing broad geographical general permits or continuing to issue conventional individual permits to agriculture point sources.

Following these events, P. L. 92-500 was amended in December 1977 to require 208 planning to include control of agricultural wastewaters within its purview. In addition, the amendments delete irrigated agriculture as a point source and irrigation return flows are exempted from the NPDES permit requirements of P. L. 92-500.

The State Water Resources Control Board is now deliberating whether to continue some type of permit system under authority of the Water Code or whether to eliminate the program. The Agricultural Advisory Committee will continue to advise the Board in this area.

208 Approach for Agricultural Wastes

Investigation of nonpoint source pollutants related to agricultural practices is being conducted primarily in the nondesignated area of the State. Categories included in the planning process are salt, pesticides, and sediment.

Salt - This major water quality issue in the San Joaquin Valley is the subject of the Interagency Drainage Program sponsored by the U. S. Bureau of Reclamation, Department of Water Resources, and the State Water Resources Control Board.

Pesticides - The majority of pesticide control planning involves agricultural drains in the Colorado River Basin and disposal of pesticide containers in the Central Valley. The Colorado River Basin Regional Water Quality Control Board, in cooperation with other federal, state, and local agencies, is conducting an extensive monitoring program of the drains and has arranged for the development of best management practices relative to pesticide use by local irrigation districts and the County Agricultural Commissioners.

Sediment - The primary study area is the Central Valley. The Central Valley Regional Water Quality Control Board and federal, state, and local districts have established Local Management Teams to develop BMPs for erosion control in a number of pilot areas where erosion is a problem. When implementable BMPs are developed, the State will designate management agencies to implement BMPs stressing voluntary compliance. Based on the success of this approach, the Regional Board will consider expanding the pilot program to other areas in the Central Valley.

INTRODUCTION
LONG-TERM WATER PROBLEM CONSIDERATIONS

William E. Warne
Water Consultant, Sacramento

In the long-term, water management in California must become total. I do not mean that every drop of rain must be collected out of natural streams and into canals and pipes. Quite the contrary. Total water management must, and will, provide for the fish and, as well, for aesthetic purposes which man requires in his own environment.

The totality I am talking about is that of conservation, of efficient use, of sustaining quality, of waste water reclamation, and of repeated reuse of the waters that are devoted to agriculture, industrial and domestic purposes in our State.

California is one of the eleven arid western states. Since the first Spanish mission was founded more than 200 years ago at San Diego, all settlements in California have been dependent on construction and continued operation of water projects. The Padres dammed the San Diego river to irrigate the mission gardens and vines. More than 80 percent of all of California's farm production--the highest by far in the nation--today comes from 8,500,000 acres of irrigated land, about 8.5 percent of the State's area. Our 22 million people could not possibly live in California without the water provided by our monumental and complex projects that divert waters over distances as great as 650 miles and lift them as high as 3,100 feet.

The drought of 1975-77, however, has taught us that in the long-term we must improve the efficiency of our water uses. I began advocating desalination 25 years ago and with the late Goodrich Lineweaver of the Bureau of Reclamation drew up the Interior Department's original plan for desalting ocean and brackish waters for supplementation of fresh water supplies.

Technologies have been developed for extension of the uses of our developed water supplies. They are being applied. We will hear about one pioneering project from Mr. Fowler.

As frequently happens, our new technologies outrun the institutional responses that they indicate are needed.

Mr. Hansen will talk about new water rights issues that are arising.

What happens when a great river is completely spent? The Colorado River's waters have been entirely stored and used for more than a dozen years. The evaporation from its great reservoirs has concentrated salts that are naturally in the stream and the return flows that enter the river have helped to make it increasingly salty at each downstream diversion point.

To improve the quality of Colorado River water that is delivered to Mexico, the Bureau is building a 100 mgd desalter at Yuma, Arizona on the Wellton-Mohawk Project drain. In the Imperial Valley, where Colorado River water is used exclusively, very advanced soil salinity control programs are in effect.

I view the drainage of irrigated land as important to the maintenance of its productivity as the watering, itself. The San Joaquin Valley must be drained as a part of our long-term water management program, and the wastewaters in both the Imperial and the San Joaquin Valleys must be viewed as resources, capable of being reclaimed and reused.

Messers Robinson and Beck will talk about these areas.

It is time, now, to raise our eyes and look searchingly into the future as earnestly as though our very lives depended on it. In a real sense, the lives of our grandchildren may. When the Persian empire ruled the Middle East 2500 years ago, the irrigated lands, now shrunken, supported at least three times as many people as live in the area today. Our civilization is similarly dependent on our region's water resources. In the absence of their wise use, in the long-term, I doubt that even 7,000,000 people, a third of the present population of California, would be found to be living here in 4000 A.D.

CALIFORNIA WATER RIGHTS LAW: THE COMMISSION AND ISSUES

David E. Hansen
Governor's Commission to Review
California Water Law, Sacramento

This paper presents background on the recently established Governor's Commission to Review California Water Rights Law, and a discussion of issues facing the Commission.

The Commission was established to: 1) review existing California water rights law; 2) evaluate proposals for change in this law; and 3) recommend appropriate legislative action. This will provide the first systematic examination of California water rights law in 64 years. The Commission is approaching its task through educational and information gathering workshops in six topical areas which cover the legal aspects of: appropriative rights, riparian rights, water conservation, groundwater rights, water rights transfers, and in-stream uses.

Increasing costs of water projects suggest that California water users will be forced to adjust to what they feel to be an inadequate water supply. In this adjustment process, conservation and greater use efficiency will have important roles. It would appear that there are many areas where important improvements could be achieved through altering existing water rights law. Riparian rights are used to illustrate some of the types of general water rights issues which are involved. Inflexible arrangements can result in inefficiencies and inequities which may worsen over time. Uncertainties for downstream users may derive from the open-ended nature of future uses which are allowed. Changes in court interpretations of what constitutes "reasonable beneficial use" may also create uncertainty. Equity problems are likely to result due to difficulties in determining a basis for compensation when rights are not quantified. Thus, in the area of riparian rights alone, important examples are found of inflexibilities, uncertainty, and equity problems stemming from compensation difficulties.

Inefficiencies resulting from water rights problems can diminish the potential contributions which agronomists can make to society. To the extent that water rights problems fail to be corrected, agronomists may be challenged to find even more innovative ways to meet the needs of agricultural systems characterized by water scarcity.

FUTURE WATER NEEDS AND SOURCES FOR CALIFORNIA

James L. Welsh
Dept. of Water Resources, Sacramento

Each year about 32 million acre-feet of water are used to irrigate 9.2 million acres of irrigated land in California and to meet the domestic, commercial, and industrial demands of 22 million people.

The 32 million acre-feet is derived from an average annual runoff of 70 million acre-feet in California and an import of the Colorado River of 5 million acre-feet.

California has dedicated substantial water to environmental uses. The Wild and Scenic Rivers Act of 1972 identifies major parts of four North Coastal streams to remain in their natural state. These streams generate 17.8 million acre-feet of water annually. Another 3.4 million acre-feet of water is dedicated to Delta outflow for water quality control, environmental maintenance, and salinity repulsion.

Thus, over 49 million acre-feet of California's water supply is presently used or reserved. Theoretically, the 26 million acre-feet remaining represents surface supplies available to meet future water needs. But, in a practical sense, half is probably unavailable for out of stream use because the runoff occurs in remote areas, small coastal watershed, interior desert areas as flash floods, or as major flood peaks which are not physically practical to regulate or conserve.

By the year 2000, we will need about 5 million acre-feet more water to meet expanding urban and agricultural needs if we continue to use water with the same efficiency as in the past. We will need another 2 million acre-feet if we are to eliminate the current ground water overdraft, that is, to balance ground water recharge and ground water use.

To meet reasonable needs for water, water conservation must become a way of life. The drought has shown us that conservation efforts can be effective. We believe per capita urban use can be reduced by 20 percent on an overall long-term basis.

By the year 2000, we believe that the agricultural and urban sectors can economically save over 2 million acre-feet per year over present rates of unit water use.

Waste water reclamation can also meet some water needs. We expect reclamation of water which would otherwise be wasted to supply over one-half million acre-feet by the year 2000.

A third category of supply sources are ways to store surplus water other than conventional surface water damsites. These include put-and-take operation of available ground water storage and use of off-stream surface storage such as San Luis Reservoir. Promising ground water areas include Southern California and in the Tulare Basin. Possible off-stream storage sites to store surplus Central Valley supplies include the Glenn Complex on the westside of the Sacramento Valley and sites along the westside of the San Joaquin Valley. Yields of up to one million acre-feet are projected by the year 2000.

We do not expect that conventional surface storage will occupy the same prominence as it has in the past since most of the better sites have been used, environmental and seismic concerns are prominent and construction costs are escalating rapidly. We do expect these sources to supply an additional three-quarters to a million acre-feet by 2000.

Weather modification or cloud seeding to increase effective precipitation is now done in a number of areas of the State. Evidence to date suggests precipitation can be increased 5 to 15 percent in many watershed areas. However, there are a number of environmental and legal concerns in addition to evaluation of effectiveness before this source can be relied upon.

California has intensively studied desalting, but, because of intensive energy requirements and high costs, we believe desalting will serve only specialized needs. We do not believe it offers an economical means to supply large quantities of water. We and others are continuing studies related to waste water reclamation, agricultural waste water, and brackish ground water.

Ground water storage was the salvation for California agriculture in drought year 1977. In normal water supply years we pump about 15 million acre-feet of ground water, over 40 percent of the total irrigation water, but in 1977 we pumped about 18.5 million acre-feet. This increase, coupled with reduced recharge, has resulted in a net reduction in storage of about 10 million acre-feet, or 5 times the long-term average.

We believe more effective management through conjunctive operation, water exchanges, and other possibilities such as redefinition of water yields and deficiencies can increase effective yields and make one million acre-feet of water available for beneficial use by the year 2000.

Senate bill No. 346 embodies the recommendations of the Department after a two-year review of the Delta, the Peripheral Canal, the future needs of the state water project and the federal CVP. It incorporates those elements deemed essential for successful water management proposals for the future. SB 346 requires that agreements be reached and federal legislation passed which will require the Bureau of Reclamation to meet the same water quality standards in the Delta that the State now meets.

These facilities would add 2.7 million acre-feet of yield annually to the State Water Project and the Central Valley Project. Importantly, the Peripheral Canal by ability to regulate surplus flows in the Delta will add one million acre-feet of yield. At current dollars, SB 346 will require 3.4 billion dollars, but at anticipated inflated dollars by the time it is completed, 7.3 billion dollars will be required. The costs of new water is now in the order of $100 to $200 per acre-foot compared to $10 to $20 only 20 years ago. While the user will pay a melded cost of water, generally from both old and new sources, water costs to those expanding uses or to new users will be at levels unheard of only a few years ago.

We are convinced that, with the methods outlined, and with the elements of SB 346, the essential water needs of California can be met.

LONG TERM CONSIDERATIONS IN SALINITY MANAGEMENT

Frank E. Robinson
Water Scientist
University of California, El Centro

The complexities of salinity management are claiming an increasing amount of political, technical, and popular attention throughout today's world. The volumes of publications addressing this problem occupy a continually increasing amount of library shelf space. Fortunately, the projections, cost estimates, suggested management practices, and field experiments are leading to corrective actions. The Colorado River basin may be utilized as an instructive example of efforts to solve salinity problems in the arid portion of the United States.

The problems encountered along the Colorado River have followed the typical historical pattern of arid irrigated areas. As irrigation was applied, the water table rose causing water logging and salt concentration. Drainage ditches were dug and later drain tile were added to expand the area of draw down of the saline water table. Hermsmeier (1977) advises that a plan for controlling water logging and salinity is an essential part of any land development program. The plan can include surface drainage, land leveling, ditching, and tiling and be constructed in segments spreading the costs over a period of years.

Upriver from the Imperial Valley agricultural developments occurred which cause a continual increase in the salinity of the Colorado River water delivered for irrigation. Studies have been conducted to estimate the damages that could occur if the long term salinity increase continues at its present rate (Robinson, 1977). Establishing a dollar loss for each mg/l increase in salinity provided a stimulus for corrective action and a reference to costs and benefits from salinity changes from new development or control measures.

A recent study (Anderson, et al., 1977) showed projected yield decreases from projected salinity increase in Colorado River water applied to several crops in California and Arizona. The greatest impact was shown in the areas of heavy soil that retain the greatest proportion of irrigation borne salts. Over a range of 900 to 1,400 mg/l total dissolved solids the yield decrements were smallest in the lower range and increased exponentially with increase in salt. Damages to municipal and industrial plumbing was similarly evaluated. Results showed damages to households two to three times greater than previous studies.

Corrective measures to reduce the rate of salt increase in the Colorado have already begun. Three of these projects include removal by pumping of saline groundwater for evaporative concentration away from the river in Las Vegas Valley in Nevada and Paradox Valley, Colorado, and a program of irrigation management improvement and ditch lining in Grand Valley, Colorado, to reduce the subsurface dissolution of salt as water moves through mancos shale back to the river (Weber, 1977). The three projects combined have a potential of removal of 666,000 tons of salts from the river annually. In addition to these three projects, there are 13 others which will further limit salt additions to the river.

At the present time District 7 of the California Regional Water Quality Control Board is developing criteria of Best Management Practices (BMP) in compliance with Section 208 of the Federal Water Pollution Control Act (Swajian, 1977). Here, as in other districts, the long range consideration is that the best management practice should strike a reasonable balance between the most desirable level of salt from an environmental point of view while still allowing a reasonable latitude of operation for the growers who must cope with the efficiencies inherent in their irrigation systems. It is imperative that those who have an appreciation of attainable efficiencies in conveyances and application systems should lend a hand to the advisory committees who are now defining the "Best Management Practices." It is quite probable that these BMP's will soon be implemented for compliance with the force of law. It is not entirely certain that the "flexibility" in the application of control or treatment requirements of irrigated agricultural activities recommended by the National Commission on Water Quality will be available (Maughn, 1976), or that the flexibility will be available in time to prevent periods of economic stress as growers attempt to meet efficiencies beyond the capability of their present irrigation systems. Improvement in irrigation efficiency often includes energy which is also under pricing and availability pressure. Hard choices will have to be made between energy and water conservation in salinity management as outlined by Hagan and Roberts (1976).

Fortunately, the choices in salinity management in the United States can be made before population increases to the marginal supplying capability of our farm land. We can make choices with economic and environmental criteria without concern about massive human malnutrition and death resulting before the proper level of regulation is achieved. Much of what we learn in our future efforts at salinity management will be applied in other parts of the world under much more urgent conditions (Robinson, 1977).

LONG-TERM CONSIDERATIONS-- SALT MANAGEMENT IN THE SAN JOAQUIN VALLEY

Louis A. Beck
San Joaquin Valley Interagency Drainage Program, Fresno

The San Joaquin Valley of California is one of the most productive agricultural areas of the United States. Approximately ten percent of the land now in production has a high water table drainage problem. Ultimately twenty percent of the Valley will have drainage problems. Figure 1 shows the San Joaquin Valley and the drainage problem area. The valley floor contains almost seven million irrigable acres (28×10^9 m^2) of which about five million (20×10^9 m^2) are in agricultural production now.

The trough of the Valley is underlain with clay strata. The leaching fraction required to maintain salt balance in the root zone builds up on these clay strata until it enters the root zone and yields are reduced. This perched water is brackish because of the concentration of the salts in the applied water by plant transpiration and resuspension of the salts deposited in the soil over the eons. Table 1 lists the area presently affected by drainage problems and future projections.

Table 1

	Present	2020	Ultimate
Drainage Problem Area (thousand acres)	400	900	1,100
Drain Water Quantity (thousand acre-feet)	60	400	600
Drain Water Quality (micromhos per centimeter)	7,500	5,000	4,500

The solution to the high water table problem is the installation of perforated pipe (subsurface drains) six to eight feet (1.8 to 2.4 m) deep. Table 1 also gives the present and projected quantity and quality of subsurface drainage water produced in the Valley. This drain water is not of suitable quality for agricultural use. A program is needed that will manage the drain water and dispose of the salts so that the ground and surface waters are not adversely affected.

In 1975 the San Joaquin Valley Interagency Drainage Program (IDP) was established by the United States Bureau of Reclamation (USBR), the California State Water Resources Control Board (SWRCB), and the California Department of Water Resources (DWR). IDP's goal is to develop a drain water management program that is economically and environmentally sound, financially feasible, and politically acceptable. IDP consists of a small independent office that does very little of the study itself. IDP coordinates the ongoing activities of the three agencies to eliminate duplication and to ensure that all alternatives are evaluated. USBR is performing the economic evaluation, SWRCB is responsible for the environmental assessments, and DWR is developing the financial program and reviewing any legal and institutional constraints.

Five basic alternative management programs have been evaluated. These are: no valleywide action; retention on land (evaporation ponds); and three methods of ocean disposal--1) directly, 2) indirectly via the San Joaquin River and 3) indirectly via San Francisco Bay. Disposal directly to the ocean or indirectly via San Francisco Bay are the most attractive alternatives. No action will allow most of the drainage problem area to go out of production. Evaporation ponds will keep the salts in the Valley and will eventually require disposal of about three million tons (3×10^9 kg) of salt annually. Disposal to the San Joaquin River will degrade the water supply for the Delta.

The San Joaquin Valley is a water short area. In non-drought years four million acre-feet (49×10^8 m^3) have been imported annually and the ground water overdraft still exceeded one and a half million acre-feet (18×10^8 m^3). Previous studies viewed the drain water as a waste to be disposed of as rapidly as possible. In light of the present situation, drain water must be considered as a resource. The salts must be eventually disposed of in a safe manner, but first the water component must be used to the greatest extent possible.

Reuse of drain water will increase project benefits; it may lower the costs; and it may provide part of the financing of a drainage program. Methods of reuse of drain water include: reclamation by desalting, power plant cooling, development of waterfowl refuge, salinity repulsion in the western Delta, recovery of salts, and agricultural reuse.

Even though development of additional water supplies for the Valley will be very expensive (maybe as high as $200 an acre-foot), desalting costs are higher. In addition, reverse osmosis and ion exchange do not remove the boron in drainage waters and additional costs would be necessary before it would be usable for agriculture. In spite of the large volumes of salts projected in the future, no chemical company has expressed any interest in studying the feasibility of salt recovery from drainage waters. Agricultural reuse and aquaculture need additional applied research before they can be deemed practical with drainage water in the Valley. SWRCB contracted with Dr. Knight of the University of California, Davis, to scope out a demonstration project to determine the practicability of aquaculture with drain water. The U. S. Department of Agriculture Salinity Laboratory at Riverside is planning a demonstration project using drainage water to irrigate cotton in the San Joaquin Valley.

The principal wintering ground for waterfowl in the Pacific Flyway is California. Up to fifteen million ducks and geese accompanied by shore birds, egrets, herons and other birds winter or pass through the Central Valley of California. At one time, most of the trough of the Valley was waterfowl habitat. Land reclamation has dewatered most of the area so only a small percentage of the original habitat remains. Additional habitat could increase the waterfowl population of the flyway. If essentially all the drain water was used, approximately 50,000 acres (2×10^8 m^2) of marshes could be developed in 2020.

Several utilities are proposing to locate power plants in the Valley. Fossil fuel or nuclear power plants would require water for cooling. The amount of fresh water required for the proposed plants is just not available. Of the alternative sources of water that have been investigated (municipal waste water, brackish ground waters, or connate waters) subsurface drain water seems most attractive if the quantities are available when required. Each plant might use between 60,000 and 100,000 acre-feet (7 to 12×10^7 m^3) annually. Treatment to prevent scaling and control biological growths would be required before use.

The Delta is a tidal estuary whose waters are used for agricultural and municipal supply. It is necessary to provide sufficient outflow to prevent intrusion of ocean salts into the Delta and protect the beneficial uses. Large volumes of fresh water are released from upstream reservoirs for this purpose. Drain water discharged into waters of similar salinity in the western Delta could assist in the repulsion of ocean salts.

Hydraulic model studies indicate drain water is about half as effective as an equal volume of fresh water. Drain water may be used to augment or possibly replace fresh water releases.

Economic evaluation by the USBR determined that a gravity canal discharging into the western Delta-Suisun Bay was the least costly alternative. Evaluation by Environmental Impact Planners for SWRCB found that an ocean discharge or discharge near Martinez would have negligible environmental effects.

Based on these studies we are now developing a plan that will consist of a gravity canal from Kern County discharging into the western Delta-Suisun Bay. Tile drainage will be collected from farms and transported to marshes or other reuses. After reuse the concentrated drain water will be transported to the disposal location. Modeling studies now being conducted will determine the discharge point and discharge regime.

After the recommended plan is completed in April, cost estimates, a financing program, and an environmental impact report will be prepared. These will be published in draft form this fall. The final report of a drainage program for the San Joaquin Valley will be published early in 1979.

GROUNDWATER RECHARGE IN SANTA CLARA VALLEY

Lloyd C. Fowler
Santa Clara Valley Water District, San Jose

The Santa Clara Valley is a 97,000 hectare valley within Santa Clara County at the south end of San Francisco Bay. The population of the area is about 1,200,000.

In 1975 this valley had an estimated total annual water use of about 462 million cubic metres. The water supply normally consists of an average annual local supply of about 520 million cubic metres and an imported supply of about 170 million cubic metres. The imported water supply actually received in 1975 totaled about 198 million cubic metres, of which about 62 million cubic metres was from the Hetch Hetchy Project which transports water from the Sierra Nevada Mountains, and about 136 million cubic metres was from the State Water Project which transports water from the Sacramento-San Joaquin Delta. About 62 million cubic metres of the State Water Project supply in 1975 was used for groundwater recharge rather than direct surface delivery. Ten reservoirs with a combined capacity of 216 million cubic metres capture local floodwater runoff for groundwater recharge. These reservoirs also provide some incidental flood control benefits and considerable recreational benefits throughout the year.

The District has operated groundwater recharge facilities for over 40 years. At present about 185 million cubic metres per year are recharged artificially through the use of offstream recharge basins and the use of natural stream channels. There are about 100 hectares of offstream groundwater recharge basins and about the same number of hectares of natural stream channels used for groundwater recharge.

It has been found that the surface area of the spreading basin is less important than the wetted perimeter. The bank area is the most important aspect of the wetted perimeter because there is apparently less clogging than on the bottom. The steeper the side slopes, the greater recharge capability; the longer the perimeter of the basin the more side slopes are available. Curvilinear basin sides provide a longer perimeter and result in a more aesthetically pleasing facility in urban areas.

Shallow groundwater recharge basins promote algae and aquatic weed growth that are unsightly and may reduce the infiltration rate through deposition of debris on the banks and bottom of the basin. Basins with a depth of three metres or more have minimal algae and aquatic weed problems and by exposing more bank surface achieve higher recharge capability. Various chemicals, including copper sulfate, are effective in reducing water surface algae. Some species of fish are also effective in controlling surface algae and aquatic weeds, although fish are adversely affected by wet-dry operation and too low or too high temperatures. They may have to be restocked or reintroduced into the pond as necessary.

The typical groundwater recharge basin is excavated to a depth of three metres or more with side slopes as steep as the soil will stand when saturated. In some soils, special protection, such as broken rock, is placed at the anticipated water surface to reduce wave action and bank erosion turbidity. Recharge basins are fenced to keep small children from entering; however, under certain circumstances, some basins are opened to recreational activities under supervision of local Parks and Recreation Departments.

Water containing more than 25 Jackson Turbidity Units should not be introduced into recharge basins because turbidity clogs the basin surface and lowers the infiltration rate. It is possible to reduce the turbidity through the use of coagulant chemicals such as alum or polyelectrolytes followed by stilling basins to settle the resulting floc prior to introducing the water into recharge basins.

Generally, the recharge basin is kept in service as long as water is available and as long as the recharge rate is in excess of 15 to 30 centimetres per day. Infiltration rates can be expected to decline from between 1.5 to 3 metres per day upon initial application of water to 0.5 to 1 metre per day within six months. Further reductions in infiltration rates occur more slowly taking from one to 1½ years before infiltration is reduced to a rate of 30 centimetres per day when cleaning is required.

When infiltration rates become low, the recharge basin is dried and the surface layer of material on the pond bottom is removed. Generally, the reduction in infiltration rate is caused by a very thin layer of fine organic and inorganic sediment collected on the surface of the basin bottom. The surface deposits are removed with mechanical equipment and stockpiled alongside the basin.

In urbanized areas, groundwater recharge basins are an asset to the community. They may be opened for recreational purposes, but swimming and powerboating should not be allowed because of their adverse effects on the infiltration rates. Sailboating and fishing have negligible effects on infiltration rates but do increase the cost of maintenance. Such urban recharge basins can have an aesthetic appeal as well. The open space area and the visual effect of water are appealing in water-short urban areas. The basins can be landscaped to make them more attractive, but this will add to the maintenance cost.

In the use of natural creek channels for groundwater recharge, water is allowed to flow down the channel in the forebay areas. Care is taken to not allow recharge waters to escape into channels that cross confined aquifer zones where no effective recharge can take place. Flowing water would generally maintain an infiltration rate but when the stream channel length in the forebay is relatively short, ponds will increase the volume of recharge. In addition, water control is more easily practiced by the construction of gravel barriers, using channel bottom material, across the stream channel at appropriate locations. The ponding by these barriers serves, in some instances, to increase the groundwater recharge through an enlargement of the wetted perimeter by exposing more bank area.

Barriers in natural channels must be equipped with spillways to allow flow from one pond to the next pond downstream. These spillways may be either pipe sections placed in the embankment or gunite concrete surfaced overflow sections. Unpredictable flashflood conditions may cause failure of the barriers and necessitate rebuilding the structures. However, when predictable heavy runoff during the winter season may cause flooding, the embankments are breached by District operating crews.

The average cost of operating and maintaining surface recharge basins is $5 to $7 per 1,000 cubic metres recharged. When the capital costs of land acquisition and construction are added, the total cost of groundwater recharge by surface spreading is about $6 to $8 per 1,000 cubic metres. The use of coagulant aids to reduce turbidity of the influent water increases the operation cost by about $2.50 per 1,000 cubic metres. These costs can be compared to the cost of injecting recharge water through pits or wells that ranges from $17 to $28 per 1,000 cubic metres.

Groundwater is extracted for use by about 6,000 active wells in the District. In order to fund the District's water management program, including the groundwater recharge activities described, the District imposes a charge on all groundwater extracted in northern Santa Clara Valley. This charge is currently $27.50 per 1,000 cubic metres if the water is used for purposes other than agricultural irrigation and $6.90 per 1,000 metres if the groundwater is used for agricultural purposes. In addition to the groundwater charge some waters are sold on the surface at the rates noted above, plus a watermaster service charge. Treated water is sold for domestic service at $60.50 per 1,000 cubic metres. A county-wide ad valorem tax is levied to support the capital costs of the aqueduct system that imports water to the District.

The effectiveness of the District's goundwater recharge program may be illustrated by a brief discussion of land surface subsidence. Land surface subsidence results when water levels are lowered too much and the weight of overlying sediments compacts the poorly consolidated layers in the alluvial fill that was previously supported by hydrostatic pressures. Besides changing land surface elevation and drainage patterns, subsidence can destroy wells by causing buckling or collapse of the well casings. Extensive lowering of groundwater levels is caused by an overdraft condition, the extraction of groundwater in excess of recharge. If groundwater levels are restored to previous elevations through artificial recharge, land surface subsidence will be stopped; but the former land surface elevations will not be restored. Prior to 1969, land surface subsidence was occurring at a rate of over 15 centimetres per year. Groundwater recharge in excess of use raised the average groundwater level from over 50 metres below ground surface in 1966 to about 25 metres below ground surface in 1975. Land surface subsidence continued until 1969 when the average depth to groundwater was 40 metres. As long as average groundwater levels can be kept above this elevation, land surface subsidence is not anticipated to occur again.